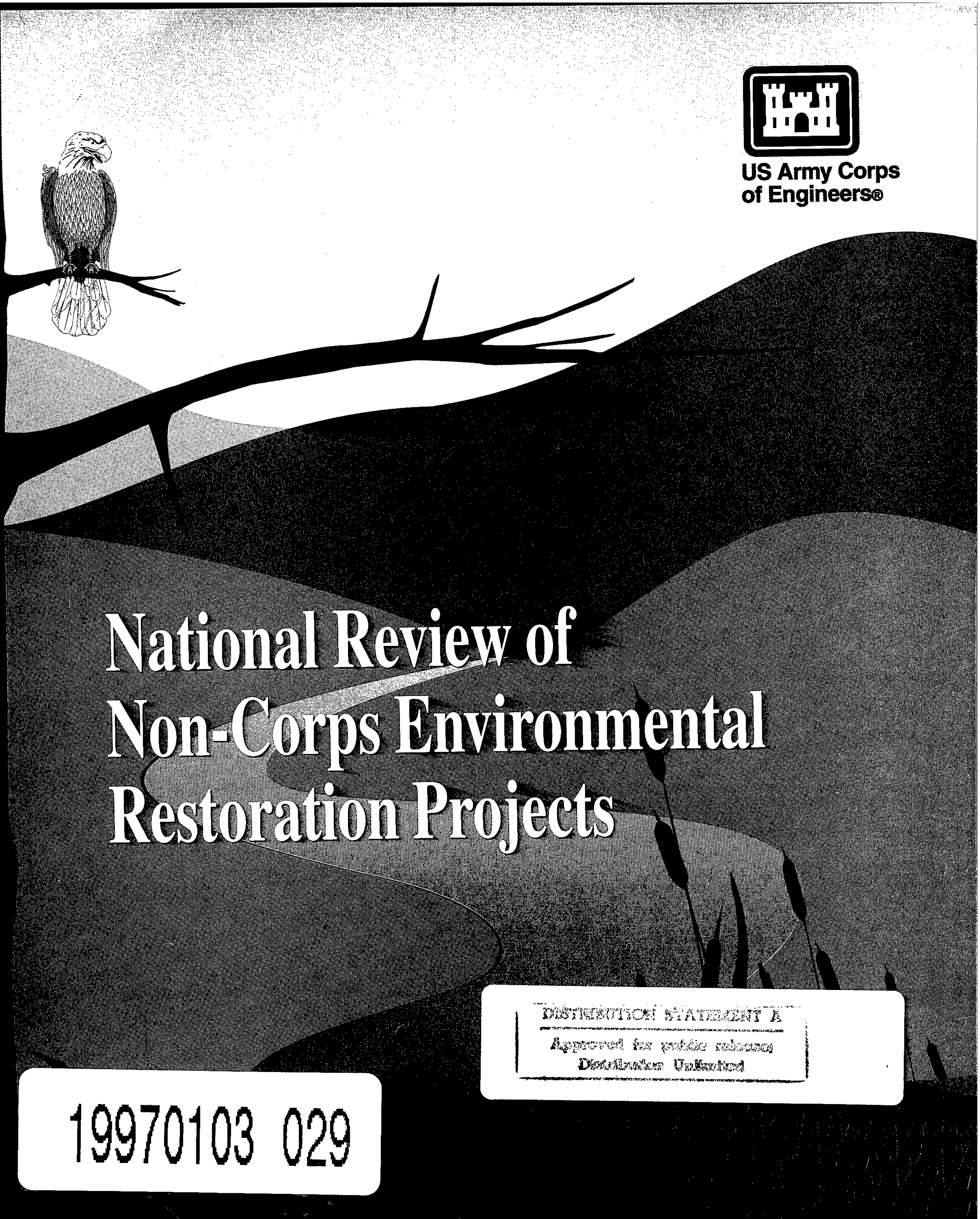



# National Review of Non-Corps Environmental Restoration Projects





*Evaluation of Environmental Investments Research Program*

December 1995
IWR Report 95-R-12

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# NATIONAL REVIEW OF NON-CORPS ENVIRONMENTAL RESTORATION PROJECTS

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# *PREFACE*

This study was conducted as part of the Evaluation of Environmental Investments Research Program (EEIRP). The EEIRP is sponsored by the Headquarters, U.S. Army Corps of Engineers (HQUSACE). It is jointly assigned to the U.S. Army Engineer Water Resources Support Center (WRSC) Institute for Water Resources (IWR) and the U.S. Army Engineer Waterways Experiment Station (WES) Environmental Laboratory (EL). Mr. William J. Hansen of IWR is the Program Manager, and Mr. H. Roger Hamilton is the WES Manager. Program Monitors during this study were Mr. John W. Bellinger and Mr. K. Brad Fowler, HQUSACE. The field review group members who provide complete Program direction and their District or Division affiliations are as follows: Mr. David Carney, New Orleans District; Mr. Larry M. Kilgo, Lower Mississippi Valley Division; Mr. Richard Gorton, Omaha District; Mr. Bruce D. Carlson, St. Paul District; Mr. Glendon L. Coffee, Mobile District; Ms. Susan E. Durden, Savannah District; Mr. Scott Miner, San Francisco District; Mr. Robert F. Scott, Fort Worth District; Mr. Clifford J. Kidd, Baltimore District; Mr. Edwin J. Woodruff, North Pacific Division; and Dr. Michael Passmore, Walla Walla District. The work was conducted under the Engineering Environmental Investments Work Unit of the EEIRP. Ms. Joy Muncy of the Technical Analysis and Research Division (TARD), IWR, and Mr. Tony Dardeau and J. Craig Fischenich of the Environmental Engineering Division (EED), WES, are the Principal Investigators.

This report is a part of the Engineering Environmental Investments - Formulating Inputs and Monitoring Effectiveness work unit of EEIRP. The objectives of this work unit are to 1) identify relevant approaches and features for environmental investment measures to be applied throughout the project life; 2) develop methods to access the effectiveness of the approach or feature for providing the intended environmental output; 3) develop and provide guidance for formulating environmental projects; and 4) provide guidance for formulating and identifying relevant cost components of alternate restoration plans.

The objective of this report was to compile management measures, engineering features, monitoring techniques, and detailed costs for a representative sample of non-U.S. Army Corps of Engineers (Corps) environmental projects or engineering projects with environmental features. This study was a companion study to a similar IWR in-house evaluation of Corps projects. Both studies will be used by the Corps to develop guidance documents for this EEIRP Work Unit. The information will be used to assist planners in the following: 1) identifying potential environmental variables that can be manipulated to improve environmental outputs; 2) identifying alternative management measures for modifying those variables; 3) identifying the various engineering features or components of those management measures; 4) determining the associated probability of success of alternative management measures; and 5) estimating their costs.

The projects represent a wide range of goals, engineering features, monitoring techniques, and costs. Success of projects was assessed relative to stated goals and criteria. In particular, the methods of calculating, projecting, and reporting costs vary considerably. In the present study, all

project information is presented in a standard format so that the data are comparable, in spite of inherent, contextual differences.

The work was performed by Pacific Northwest Laboratory, operated by Battelle Memorial Institute under terms of a contract with the U.S. Army Corps of Engineers, IWR. Dr. Ronald M. Thom was the Project Manager. Ms. Joy Muncy was the Contract Manager.

The report was prepared under the general supervision at IWR of Mr. Michael R. Krouse, Chief, TARD; and Mr. Kyle E. Schilling, Director, IWR; and at EL of Mr. Norman R. Francingues, Chief, EED, and Dr. John W. Keely, Director, EL.

A number of individuals with personal experience in various aspects of environmental restoration provided input to this report. Without their generous assistance, this report would never have come to fruition.

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# *I. INTRODUCTION*

## BACKGROUND

Throughout the United States, there is an increased awareness and concern for the protection and restoration of environmental resources. Indeed, recognizing that humans have the potential to alter the Earth irreversibly, and that global population is increasing at an; estimated rate of 92 million per year, the need for protection and restoration of environmental resources is evident and urgent. The growing number of conferences, journals, and books pertaining to environmental restoration amply illustrates this theme (Shreffler and Thom 1993). The National Research Council (NRC) report, *Restoration of Aquatic Ecosystems* (NRC 1992), stressed that failure to restore aquatic ecosystems promptly will result in sharply increased rates of extinction of species or ecosystem types, and in permanent ecological damage. NRC recommended that a national restoration program be developed for United States aquatic ecosystems to achieve a net gain in all aquatic resources. The ambitious goals of this program include restoration of 400,000 miles of river-riparian ecosystems, two million acres of lakes, and 10 million acres of wetlands by the year 2010.

Within the U.S. Army Corps of Engineers (Corps), new Congressional authorities are providing more opportunities to pursue environmental restoration initiatives. This increased emphasis on environmental restoration, however, brings a concomitant need for improved techniques for evaluating and comparing environmental restoration projects and programs. Whether monetary or nonmonetary metrics are used, the Corps needs measures of the efficiency and effectiveness of alternative environmental projects and programs in order to better allocate limited resources.

To address these issues, the Corps has initiated the Evaluation of Environmental Investments Research Program (EEIRP). Overall management of this program has been assigned to the Corps Water Resources Support Center, Institute for Water Resources (IWR). The 3-year research program is intended to provide Corps planners with methods and techniques to aid in developing supportable environmental restoration and mitigation projects and plans. In addition, the EEIRP will develop a framework to provide decision makers with information to facilitate the allocation of limited funds among a range of proposed projects and programs. To accomplish these objectives, the research program has been divided into 10 specific study areas, called work units. The present report is provided as input to the Engineering Environmental Investments: Formulating Inputs and Monitoring Effectiveness (EEIFIME) Work Unit.

## SPECIFIC STUDY PROBLEM

The Corps has been involved in environmental restoration through current and past activities in environmental design of waterways projects, cultural and natural resource projects, the Department of Defense (DoD) Environmental Quality Strategic Research and Development (R&D) Plan, and the Tri-Agency Strategic Environmental Research and Development Program (Environmental Protection Agency, DoD, Department of Energy). However, despite its demonstrated leadership role in environmental restoration, the Corps lacks an integrated approach across programs and organizations that provides methods and procedures to formulate, design, and estimate costs for environmental restoration projects. The Corps has a mandate to include environmental features in all Corps projects at the earliest planning phase and to aggressively advocate environmental considerations through all phases of the project life. Yet, little guidance is available to assist planners in the following areas: 1) identifying potential environmental variables that could be modified to improve environmental outputs; 2) identifying alternative management measures for modifying those variables; 3) identifying the various engineering features or components of those management measures; 4) determining the associated probability of success of alternative management measures; and 5) estimating their costs.

## OBJECTIVES

The objective of the present study performed by Pacific Northwest Laboratory (PNL) was to compile and compare management measures, engineering features, monitoring techniques, and detailed costs for a representative sample of non-Corps environmental projects or engineering projects with environmental features. Case histories for non-Corps projects from various geographic areas throughout the United States were compiled. The PNL study is a companion study to a similar IWR in-house evaluation of Corps projects. In addition, IWR has developed a prototype information tree for environmental restoration plan formulation and cost estimation. These will be used by the Corps to develop guidance documents for EEIFIME Work Unit problems.

## ORGANIZATION OF THIS REPORT

Section II describes the methods employed to acquire the information. Section III presents a matrix of all projects that are included in this study that resulted from the search. The project descriptions and cost analyses are presented in Section IV. Conclusions from the search and review are given in Section V. Finally, appendices provide some additional information that could be of use in development of restoration project engineering features and costing.

# *II. METHODS*

## TELEPHONE INTERVIEWS AND QUESTIONNAIRES

To identify appropriate environmental restoration projects for the present study, a review was conducted of relevant abstracts from recent conference proceedings (e.g., Society of Wetland Scientists 1994 Annual Meeting, Society for Ecological Restoration 1994 Annual Meeting), a search for restoration projects documented in the published literature was conducted, and colleagues within the restoration community were contacted. Restoration experts or individuals with specific knowledge about particular restoration projects were interviewed over the phone. Telephone interviews were conducted between September 1994 and March 1995. A concerted effort was made to maximize the diversity of projects, in terms of both geographic location and project type. Following the initial telephone interviews, interviewees were requested to fill out and return a questionnaire. The questionnaire was jointly developed by PNL and IWR to ensure that the most useful possible information was obtained for each project. In some cases, the project contact filled out and returned the questionnaire independently. In other cases, the interviewer from PNL filled out the questionnaire during a follow-up interview. Project contacts were also asked to provide monitoring reports, construction plans, maps, and any other relevant information that would otherwise not be captured in the questionnaire.

## PROJECT DESCRIPTIONS AND MATRIX DEVELOPMENT

Information from the questionnaires and supplemental project documentation provided by project contacts were used to develop two- to three-page summaries for each project. These project summaries all follow a consistent format, which provides the point of contact, project description and location, engineering features, monitoring techniques, and references. An overall summary matrix was developed for the projects reviewed. The matrix captures the highlights of each project to enable the user to select a project of interest, then to use the appropriate project description to determine the point of contact for the particular project and to read about the project in greater detail.

## DETAILED COST ANALYSIS

A detailed cost analysis was done for all projects with adequate cost information available. Costs were updated to 1994 using EM 1110-2-1304, where possible, and the Consumer Price Index; otherwise, costs were identified by year (such as "1987 dollars"). The source of the data for the projects was from interviews, reports, and other documents provided by the project contacts. Common features in the cost estimates were used to compile unit costs for each feature type. This analysis provided a range of costs for each of the major features.

## *III. MATRIX OF PROJECTS*

Over 200 non-Corps projects were identified in the initial search of literature on restoration. Of these, a total of 91 was pursued through telephone calls and questionnaires. The 91 projects appeared to be the most relevant in terms of their implementation of water-related restoration and of their economic and ecological documentation. The data acquired on 39 of these projects were complete enough to include in this report (Table III.1). Many projects did provide costing data, but the detail was so limited about unit costs, timing, labor costs, and other categories, that the data were not useful. Projects with no or limited costing data are included here if they represent significant potential sources for other types of information, if they are significant national programs, or if they provide a review of several projects.

Some of the projects represent programs that consist of a large number of similar projects. For example, the Connecticut Department of Environmental Protection (DEP) has two programs that provide assistance to projects that enhance either wetlands or coastal habitats. The information provided by the DEP listed 63 projects that were in various stages of review and implementation. Costing analysis and limited descriptions of four of the projects (all included under one program in the matrix) are provided. This program would be a valuable resource for ongoing restoration cost information. Another significant source of information is the review of stream restoration projects in California. Although cost information was limited to total project costs, engineering features were also described in the documents provided by the project contact.

The projects are categorized into 16 types, based on the projects' primary features. The number of projects within each type (shown in parentheses) is as follows: bottomland hardwood forest restoration (1), enhancement of fish and wildlife habitat (1), estuarine wetland creation (2), estuarine wetland enhancement (2), estuarine wetland restoration (4), estuarine wetland restoration and wildlife enhancement (1), mitigation bank establishment (1), stream enhancement (1), stream restoration (5), water quality remediation (1), wetland creation (5), wetland creation and enhancement (1), wetland enhancement (4), wetland mitigation (3), wetland restoration (6), and wetland restoration and enhancement (1). There are three basic activities involved--creation, restoration, and enhancement--defined by the National Research Council (1992) as follows: creation is bringing into being a new ecosystem that previously did not exist on the site; restoration is the return of an ecosystem to a close approximation of its previously existing condition; and enhancement is improvement of a structural or functional attribute of an ecosystem.

## Table III.1. Summary Matrix of Restoration Projects

| Project Name | Location | Type of Project | Primary Project Goals | Major Engineering Features | Monitoring Techniques | Project Performance |
|---|---|---|---|---|---|---|
| Hall Branch Restoration | FL | Bottomland Hardwood Forest Restoration | Establish a forest of indigenous trees and undergrowth similar to the natural bottomland forests of the South Prong Alafia River | No physical structures were built | Annual monitoring since 1985 of trees species, density, and height at project site and control wetland immediately downstream | Both short-term and long-term performance criteria have been met |
| Washington State Ecosystem Conservation Program | WA | Enhancement of Fish and Wildlife habitat | Create specific hydrologic or vegetation conditions that benefit fish and wildlife | Excavation, blasting, fencing, planting, dike construction, and channel construction | Project specific, but typically includes photo documentation, wildlife observations, and mapping at least once per year | Most of the 100+ projects are meeting performance criteria |
| Slip 5 Fisheries Mitigation Area | WA | Estuarine Wetland Creation | Construct 2.7 acres of intertidal and shallow subtidal beach and enhance prey resources for juvenile salmonids | Graded shoreline and placed riprap; constructed mitigation beach; placed gravel substrate on beach; constructed wave attenuation structures | Beach topography surveys; surficial sediment surveys; diving surveys; epibenthic invertebrate densities; fish densities | Ecological performance criteria were met within 4 years |
| Broad Dyke Marsh Rehabilitation Project | DE | Estuarine Wetland Enhancement | Improve water quality, reduce storm flooding, increase biological diversity, improve wetland habitat, improve recreation, control mosquitos, control nuisance plants, education | Dredging, excavation of dike, grading of road, water control structures, duck boxes, plantings, plant control | None yet developed | None |
| Doran Beach March Enhancement Project | CA | Estuarine Wetland Enhancement | Enhance wetland marsh habitat for wildlife | Excavation of a tidal marsh | None | None |
| Elk River March Restoration | WA | Estuarine Wetland Restoration | Restore stable and functioning salt marsh system | Breached dike; transplanted sedge | Vegetation community at Elk River and control site has been monitored along permanent transects once annually since 1987 | Seven years of monitoring data suggest success; however, plant community remains in a state of rapid change and differs significantly from control marsh |

Table III.1. (continued)

| Project Name | Location | Type of Project | Primary Project Goals | Major Engineering Features | Monitoring Techniques | Project Performance |
|---|---|---|---|---|---|---|
| Gog-Le-Hi-Te Wetland Restoration | WA | Estuarine Wetland Restoration | Restore habitat to support juvenile salmon, waterfowl, shorebirds, raptors, and small mammals | Constructed river dike and flood control dike; excavated solid waste landfill; re-routed gas pipeline; contoured wetland topography, transplanted sedge | Assessment of functional attributes relative to reference sites or literature documentation; highly effective method | Appears successful after 9 years of rigorous monitoring |
| Palo Alto Harbor Improvements/Marsh Restoration | CA | Estuarine Wetland Restoration | Provide habitat for endangered and threatened salt marsh species | Excavation of land, plantings, bicycle and pedestrian path construction, vista points | None | None |
| Salmon River Estuary Restoration | OR | Estuarine Wetland Restoration | Full restoration of the estuary to pre-disturbance conditions | No physical structures were built; this project involved simple dike breaching | Standardized empirical field studies; annual vegetation surveys in 120 permanent plots and 350 non-permanent plots; elevation surveys; salinity, soil texture, and sediment accretion measurements | Widely cited as one of the best examples of estuarine restoration in the Pacific Northwest; however, the recovering salt marsh differs from the "pre-disturbance" system in terms of elevation and hydrology |
| Spencer Island Wetland Restoration and Wildlife Enhancement | WA | Estuarine Wetland Restoration and Wildlife Enhancement | Restore tidal inundation and salt marsh on southern island; to enhance palustrine wetland on north island | Constructed cross levee to restrict tidal inundation to the south island; breached existing dike in 3 places; installed 5 water control structures | Standardized monitoring protocols for tide gauge, current velocity, aerial photo analysis, elevation surveys, emergent vegetation biomass, forest community biomass, waterfowl diversity and use, fish prey abundance, fish access and diversity | Too soon to tell; dike breached in fall of 1994 |
| Prairie Creek Fish and Wildlife Habitat Enhancement Project | CA | Stream Enhancement | Control streambank erosion and to restore high quality instream and riparian habitat | Fencing riparian corridor; planting riparian vegetation; streambank stabilization using rock riprap with willow mattresses, tree and limb deflectors, willow frames, brush bundles, post and wire fence revetment, and willow terraces | Site visits, visual observations of stabilization structures, quantification of transplant survival | Rock riprap with willow mattress and tree and limb deflectors were 100% effective in stablizing bank; 70-75% survival of planted riparian vegetation after 2 years |

Table III.1. (Continued)

| Project Name | Location | Type of Project | Primary Project Goals | Major Engineering Features | Monitoring Techniques | Project Performance |
|---|---|---|---|---|---|---|
| McDonald Creek Restoration Project | CA | Stream Restoration | Reduce sediment input from streambank erosion and to improve spawning and rearing habitat for cuthroat and steelhead | Double wing deflector, digger logs, high profile digger logs, redwood baffles | Site visits, visual observations of stabilization structures, quantification of transplant survival | All 6 instream structures functioned as designed to reduce sediment input; 85% survival of trees planted; efforts to monitor fish populations are ongoing |
| Mill Creek Channel Improvements | PA | Stream Restoration | Control stream bank erosion and provide a well-defined maintenance channel | Install gabion walls, install culverts | None | None |
| Stream Restoration Projects | CA | Stream Restoration | Management of sediment in streams and rivers | Import gravel, construction of side channels, release flushing flows, sediment traps, excavation, restore riparian vegetation | Fluvial geomorphology, water quality, biological habitat, photodocumentation | Monitoring results are provided for some projects |
| Tryon Creek Restoration Project | CA | Stream Restoration | Restore instream fish rearing and spawning habitat and riparian wildlife habitat; to increase open water habitat for birds | Dredging, fencing, planting | Twice monthly bird surveys for a 1 yr period following construction; before, during, and after photo documentation; ongoing general observations; water quality survey, vegetation survey, fish and invertebrate survey | Performance is terms of fish rearing and spawning is unknown (i.e., poorly documented); bird use is significant and includes one bald eagle and one peregrine falcon |
| Upper Little Swatara Creek Adopt-A-Stream Project | PA | Stream Restoration | Alleviate stream bank erosion and restore stream physical features | Install deflectors, cattle crossing, install mud sills, riprap banks, fencing | Annual visual inspections | Revegetation of stream banks by willow and reed canarygrass, physical structures blending well with natural surroundings |
| Water Quality Monitoring & Assessment of Agricultural BMPs | FL | Water Quality Remediation | Identify viable BMPs that are effective in reducing nutrient and sediment loads to receiving waters | Only non-structural BMPs have been evaluated | Weekly monitoring during growing season (January to May); standard water quality monitoring techniques for ground and surface water; tissues analysis of crops, atmospheric deposition, yield assessment | Project performance is directly related to meteorological conditions; modeling helps to fill data gaps and adjust results according to weather conditions |

Table III.1. (continued)

| Project Name | Location | Type of Project | Primary Project Goals | Major Engineering Features | Monitoring Techniques | Project Performance |
|---|---|---|---|---|---|---|
| Clinton County Solid Waste Authority Mitigation Wetland | PA | Wetland Creation | Provide permanent replacement for 2.33 acres of wetlands impacted by landfill construction | Compacted clay liners, 6 wetland basins, outlet headwalls | Quantitative vegetation surveys, visual documentation, shallow water monitoring wells | Results of 1 year (1994) monitoring not yet available; 5 years of monitoring will tell whether the system performs well relative to performance goals |
| Hard Rock Mine Construction Wetland | AL | Wetland Creation | Reduce Fe, MN, and TSS concentrations in acid mine drainage to compliance levels in a cost-effective, environmentally sound manner | Two anoxic drains, 2 oxidation ponds, 5 cells, 1 diversion dam and conveyance, 2 cell liners, 1 emergency spillway | Wastewater characterization and site hydrology monitoring included groundwater, soil, water chemistry, and macrobenthos using standard EPA methods; also water quality and flow monitoring, and anoxic limestone drain performance data | System met NPDES compliance requirements |
| Highway 237 Wetland Mitigation Site | CA | Wetland Creation | Create new seasonal wetlands by creating seasonal ponding | Excavation of 3 ponds, installation of 3 water control structures | Hydrology, sedimentation, vegetation, soils and wildlife using quantitative field methods | Monitoring in 1993 showed that the system was occupied by a large number of bird species and that vegetation was developing as predicted |
| Municipal Wastewater Treatment By Constructed Wetlands | KY | Wetland Creation | Evaluate the relative advantages and disadvantages, cost-effectiveness, and design and operation factors of 3 types of constructed wetlands | Three types of wetlands created; Benton - gravel marsh and surface flow marsh, Hardin - soil bed marsh, Pembroke - marsh-pond-meadow) | Vegetation surveys, water quality monitoring | All 3 systems successful at reducing BOD, TSS, and fecal coliform, but not $NH_3$-N to meet permit limits; vegetation species not a significant factor in overall performance |

Table III.1 (continued)

| Project Name | Location | Type of Project | Primary Project Goals | Major Engineering Features | Monitoring Techniques | Project Performance |
|---|---|---|---|---|---|---|
| Tidal Marsh Construction | MD | Wetland Creation | Physically restore shores to former higher elevations; to assure that the restored shore slopes are sufficiently stable to allow the construction of a sustained tidal marsh vegetation community | Surface containment structures, sandy fill, stormwater management swales, goose exclosure fence, vegetation planting | No standard techniques | Based on 216 marsh construction projects, this bioengineering restoration technique is quite successful in controlling upland bank erosion |
| Kennedy Park Wetland Creation and Enhancement | CA | Wetland Creation and Enhancement | Enhance wildlife habitat values and wetland diversity | Installation of water control structures | None | None |
| Cowlitz Wildlife Enhancement, Rainy Creek Dike | WA | Wetland Enhancement | Create permanent water source to improve waterfowl nesting habitat | Construct dike to create impoundment, install a water control well | Not specified yet | None |
| Roberts Landing Wetland Enhancement | CA | Wetland Enhancement | Mitigate for the filling of 13 acres of non-tidal wetland | Excavation, debris removal, channel construction, culvert installation, levee repair, island construction | No monitoring performed yet | Cannot be determined yet |
| San Leandro Shoreline Marshlands Enhancement Project | CA | Wetland Enhancement | Restore full or partial tidal action to three areas | Excavation of channels, construct habitat islands, install water control structures, riprap shoreline, repair levees, remove debris, remove culverts, install sign posts | None yet | None |
| Triangle Marsh | CA | Wetland Enhancement | Enhance biological productivity, habitat diversity, water quality, reduce mosquito breeding, flood prevention | Install culverts, enlarge channels, create small pond | Five-year monitoring of hydrology, sedimentation, vegetation, birds, benthic invertebrates, water column fish and macroinvertebrates | After two years tidal flushing and other features resulted in marsh vegetation with higher vigor, occupation by birds, and transient use by fish |

Table III.1. (continued)

| Project Name | Location | Type of Project | Primary Project Goals | Major Engineering Features | Monitoring Techniques | Project Performance |
|---|---|---|---|---|---|---|
| Cascade Crossing Wetland Mitigation Project | MI | Wetland Mitigation | Create 66 acres of compensatory wetland mitigation intended to function primarily in support of waterfowl | Two earthen berms, 2 concrete spillways, 2 riprap spillways | Wetland delineation (1987 manual); quantitative vegetating sampling, photo documentation at established reference points, aerial photo documentation, waterfowl sampling | First year monitoring indicates hydrology has been restored at the site, but 4 more years of monitoring will be required before performance can be evaluated |
| Indian River Boulevard North Extension Project | FL | Wetland Mitigation | Provide economical and effective mosquito control; to enhance natural resources by restoring tidal connection to the lagoon system; improve water quality; control/remove exotic vegetation | Seven exchange culverts, 2 intenral culverts, 6000 GPH electric pump; no dredging or filling required | Monthly monitoring of temperature, sailinty, pH, turbidity, and dissolved oxygen | Water quality has been satisfactory and mosquito production has been controlled; exotic die-back has occurred in most low marsh areas |
| Sweetwater Marsh Mitigation | CA | Wetland Mitigation | Provide foraging, nesting, and refugia habitat for least tern and light-footed clapper rail; to establish saltmarsh bird's beak | Construction of tidal channels; grading of wetland topography | Comparative studies to determine functional equivalency to existing reference wetlands; parameters include soils, vegetation, epibenthic invertebrates, fish, channel benthos, and birds | Based on soil, nutrient, vegetation, and epibenthos data, <60% functionally equivalent to erference wetland |
| Christmas Tree Marsh Restoration | LA | Wetland Mitigation | Convert dead-end abandoned oil canals to marsh habitat; recycle discarded Christmas trees; study type and duration of fertilizer needed to accelerate the process; educate public on recycling, coastal erosion, and loss of wetlands | Thirteen brush fences, 1100 large tree bundles for airlift to fill the canals; 1000 small bundles for brush fences | Monitoring twice/year for mat measurement and botanical survey; site specific studies on fertilizing regimes and water quality management | Initial assessment (after 2 years) suggest success, but only long-term monitoring will confirm the canals are functioning marshes |

Table III.1 (continued)

| Project Name | Location | Type of Project | Primary Project Goals | Major Engineering Features | Monitoring Techniques | Project Performance |
|---|---|---|---|---|---|---|
| Connecticut Department of Environmental Protection: Wetland Restoration (4 Projects) | CT | Wetland Restoration | Restore stream habitat for wildlife | Channel and ditch cleaning, pond connection | None yet | None |
| Des Plaines River Wetlands Demonstration Project | IL | Wetland Restoration | Restore and create riverine wetlands, prairie, and forest; to research the biological, chemical and physical characteristics of wetlands; to educate the public, scientists, and policy makers about the functions and values of wetlands | Submerged aquatic ledges, channels and dikes, 6 experimental wetlands, irrigation system, public use facilities, trails and bridges | Focused on how (1) differing hydraulic loading rates affect water/sediment chemistry, sedimentation rates, plant community development, and primary productivity; and (2) invertebrates, herpetofauna, birds, and mammals responded to restored habitats | Very successful, wetland dependent macrophytes and macroinvertebrates have increased and 2 state-designated endangered species are now breeding on the site. More than 80% of pollutants successfully removed from river |
| Metzger Marsh | OH | Wetland Restoration | Demonstrate practices for restoring and protecting coastal wetland habitat through revegetation, while concurrently restoring natural hydrologic functions and increasing habitat for species such as muskellunge, northern pike, and black duck | Dike, 5 bay fish access/water control structures, water maintenance pump structure | Stratified random design for sampling fish, small mammals, herpetofauna, macroinvertebrates, plankton, waterfowl, and plant communities, aerial photographs; GIS mapping; geologic studies; water quality studies | Complete system not done until 10/96; preliminary monitoring report will be out end of 1995 |
| NRCS Wetland Reserve Program | WA | Wetland Restoration | Restore wetland features to former agricultural land | Remove dikes, remove drain tiles, plant trees and shrubs | General observations and photographs taken annually | No results yet |
| Shaker Trace Wetland Complex | OH | Wetland Restoration | Restore a functioning wetland system on original hydric soils; to provide habitat for a diversity of plants and wildlife | Six dams, 6 outflow structures with gate valves, 4 compacted-clay dikes, clay barrier, 35 potholes | Vegetation surveys, weekly monitoring of amphibians, reptiles, birds, and aquatic insects | Diversity of waterfowl present at site, but monitoring data not yet available for public release |

Table III.1 (continued)

| Project Name | Location | Type of Project | Primary Project Goals | Major Engineering Features | Monitoring Techniques | Project Performance |
|---|---|---|---|---|---|---|
| Rincon Bayou--Neuces Marsh Wetlands Restoration & Enhancement Project | TX | Wetland Restoration and Enhancement | Demonstrate the benefits of introducing freshwater into a coastal estuary by means of a wetland marsh system | Overflow channels, dikes, low water crossing, access roads | Stratified random sampling at treated and untreated sites; parameters include primary productivity, macrophytes, infaunal populations, water chemistry, contaminants in biota and sediments, GIS mapping of vegetation | No monitoring yet; construction began January 1995 |
| Campbell River Estuary Enhancement | British Columbia | Estuarine Wetland Creation | Enhance wild salmon productivity | One supratidal and four intertidal islands | No standardized monitoring techniques; monitoring has included (1) vegetation growth, colonization, and productivity, (2) sampling of zooplankton and meiofauna and (3) studies of the use of estuarine habitats by wild juvenile salmonids | Assessment of the productive capacity of the new habitats for wild juvenile salmonids was confounded by a number of factors; system met other goals |
| North Fraser Harbour Habitat Compensation Bank | British Columbia | Mitigation Bank | Construct stable and viable marsh habitat to be used for habitat compensation for future development proposals | Rock berms; trucking sand and topsoil to the site; fabricating marsh soil; placing and grading marsh soil, harvesting donor vegetation and transplanting | No standardized monitoring techniques; vegetation coverage must equal 75-80% within 5 years; monitoring has included observations on site stability, elevation survey, soil analysis, vegetation % cover and shoot density survey | Preliminary indications are that the habitat bank is performing well; 5 years of monitoring will tell |

The primary goals are reestablishing historic vegetation, restoring or enhancing habitat for wildlife and fish species, stabilizing shorelines, controlling mosquitoes, treating wastewater, and restoring hydrology. Many of the projects were conducted as mitigation designed to offset impacts from other projects. However, many of these mitigation projects use sites that are degraded in some way and attempt to restore the former natural, undisturbed, qualities of the site. In general, such a practice is logical, because sites that historically were fully functioning systems (e.g., wetlands) and that are suitable for removal of disturbances have the highest probability for successful restoration (NRC 1992).

The engineering features cover a wide range of activities. The Natural Resource Conservation Service (NRCS) Wetland Reserve Program specifically targets agricultural land that can be relatively easily returned to wetlands. These projects typically involve very little physical work but can include activities such as removal of impediments to hydrology. Other projects, such as the North Fraser Harbor Habitat Compensation Bank, involve a wide variety of actions. In Section IV, these actions are further described and the costs for conducting each activity are provided.

Monitoring techniques also ranged widely from essentially none to very complex and integrated sampling and modeling studies. There was no project that exclusively relied on established procedures, such as the Habitat Evaluation Procedure (HEP) or the Wetland Evaluation Technique (WET), although some projects employed these techniques during part of the assessment or planning phase. Monitoring ranged from the very general, such as observations and photographs taken annually (NRCS Wetland Reserve Program), to highly quantitative studies involving physical, chemical and biological sampling (Gog-Le-Hi-Te Wetland Restoration). This broad range indicates that although standardized techniques exist, they have not been widely applied.

All projects with monitoring information covering more than one year indicated some level of success. Success was assessed relative to goals and criteria for the projects. Because monitoring varied so widely among projects, success measures varied widely. Hydrology, plant growth and cover, and bird use were most often cited as clear indicators of the performance of the system.

# *IV. PROJECT DESCRIPTIONS AND COST ANALYSIS*

## INTRODUCTION

This section contains the project descriptions, which include cost analysis. The projects are listed in the same order as presented in Table III.1. The points of contact are provided to follow up for more information. All of the contacts were helpful in acquiring information and would be receptive to further inquiries about their projects.

The descriptions are taken primarily from reports or other documents provided by the contacts. Detail varies according to the amount of information available for each project. The reports are cited at the end of each project.

## PROJECTS IN THE UNITED STATES

### Hall Branch Restoration, Florida

Point of Contact:

Dr. Andre F. Clewell
A. F. Clewell, Inc.
Route 7, Box 1195
Quincy, FL 32351
Phone: (904) 875-3868

Project Description and Location:

A 3.80-acre cypress bottomland hardwood forest was restored on a phosphorous mining site southeast of Tampa, Florida. The project site and most of its watershed were mined in 1983.

Project Goals/Objectives:

The restoration objective was to establish a forest of indigenous trees and undergrowth similar to the natural bottomland forests of the South Prong Alafia River system (Clewell 1994). The restored wetland consists of 2.25 acres of intentionally created marshes and 1.55 acres of land along newly formed stream channels.

The short-term performance criteria were that at least 400 indigenous trees per acre and at least 200 trees per acre in any acre-sized area were to be growing at the reclamation site at the end

of the first full growing season after revegetation activities occurred. The long-term performance criteria, to be assessed four years later, were at least 33 percent cover of trees, at least 20 percent cover in any acre-sized area, and weedy herbaceous vegetation was to be declining in response to vigorous tree growth.

Engineering Features:

No physical structures were built. Mine pits were filled to the approximate original grade in 1984 with sand tailings and overburden. Final grading was completed in October 1984. Two shallow depressions were excavated with a bulldozer to create marshes along the future course of the replacement stream. In March 1985, topsoil from a donor marsh was spread 3 to 6 inches deep throughout the two depressions; the donor marsh was located nearby in an area scheduled for mining. The imported topsoil contributed organic matter. The upper of the two marsh depressions (upper marsh) comprised 1.85 acres and the lower depression (lower marsh) covered 0.4 acres. Within a few weeks, the depressions were densely vegetated with marsh plants that were transferred in the topsoil as seeds and rootstocks. The most abundant species were knotgrass, maidencane, and soft rush. These marshes functioned to stabilize the substrate, clarify runoff from the surrounding watershed, and protect newly planted trees from sun and wind. Water from runoff and seepage accumulated at both marshes in all seasons. Overflow from the upper marsh cut a channel into the lower marsh. Overflow from the lower marsh then cut another channel that connected directly with unmined portions of the project site. The new stream channels were later widened and stabilized with vegetation.

In June 1985, 2,662 nursery-grown trees 1.5 to 4 feet tall were planted in the replacement wetland. These trees were mostly pond cypress, Carolina ash, red maple, sweetbay magnolia, and American elm. Concurrently, 400 nursery-grown plants of maidencane were planted in the marshes. In July 1988, 2,700 containerized trees were planted in the replacement wetland. These trees consisted mostly of red maple, laurel oak, water oak, swamp bay, sweetbay magnolia, Carolina ash, sweetgum, dahoon holly, American elm, and bald cypress. Once the planted trees were large enough to provide shade needed to protect undergrowth plants, 1,460 individual plants representing 24 species of undergrowth were transplanted directly into the replacement wetland in March and April 1989.

Monitoring Techniques:

Annual monitoring has been conducted at the site since 1985. Tree species, density, and height data have been collected along vegetation transects and compared with data from an undisturbed control wetland immediately downstream of the project site. The abundance of nonarboreal vegetation was sampled by point interception at 1-foot intervals along tape measures placed on the center lines of the vegetation transects. Both short-term and long-term performance criteria have been met. The 1993 monitoring report (Clewell 1994) documented 1,883 indigenous trees per acre (criterion was 400 trees per acre), 1,152 or more trees per acre in each acre-sized area

(criterion was 200 trees per acre), 60 percent cover of trees that were at least 6 feet tall (criterion was 33 percent cover), at least 37 percent cover in any pair of adjacent transects (criterion was 20 percent cover), and 85.6 percent of the plant species from the control wetland were represented at the project site (criterion was unspecified diversity of wetland forest undergrowth plants).

This project has been recognized in the wetlands literature (Kusler and Kentula 1990; Mitsch and Gosselink 1993) and a popular journal (Scientific American 1994) as a success. According to Clewell (personal communication, November 1994), keys to the success of this project were as follows:

1. Integration of the project site into the landscape of the watershed

2. Precise reconstruction of former hydrology in terms of elevations and grades

3. Frequent inspections and maintenance throughout the life of the project

4. No fiscal restraints; the client trusted the restorationist to do the job correctly.

Cost Analysis:

No details are available on the costs of the Hall Branch Restoration Project. The costs were about $24,000 per acre in 1986 (total = $91,200) (Table IV.1). The contractor estimates that with one-third less monitoring (an amount he considers more reasonable) he could have saved nearly $9,000 an acre and could have used up to one-third of that to do additional site work.

TABLE IV.1. Cost by Component, Hall Branch Restoration

| Project Component | Quantity | Unit | Equipment, Materials, Supplies, etc. | Labor | Total Costs ($1994) |
|---|---|---|---|---|---|
| Grading, tree planting, transplanting, herbicide control, monitoring | 3.8 | acre | Costs not given separately | | $116,660 |

Sources:

Clewell, A.F. 1994. *Vegetational Restoration at Hall Branch Reclamation Area, 1993 Monitoring Report.* A.F. Clewell, Inc., Quincy, Florida.

Kusler, J.A., and M.E. Kentula, eds. 1990. *Wetland Creation and Restoration - the Status of the Science.* Island Press, Washington, D.C.

Mitsch, W.J., and J.G. Gosselink. 1993. *Wetlands*. Van Nostrand Reinhold, New York.

Holloway, M. 1994. "Nurturing Nature." *Scientific American* 270(4):98-108.

SCS (Soil Conservation Service). *Directory of Wetland Plant Vendors.* 1992. WES TR WRP-SM-1, November 1992. U.S. Department of Agriculture, Washington, D.C.

**Washington State Ecosystem Conservation Program, Washington**

Point of Contact:

Mr. Dave Kaumheimer
U.S. Fish and Wildlife Service
P.O. Box 1157
Moses Lake, WA 98837
Phone: (509) 765-6125

Project Description and Location:

Over 100 individual projects have been completed under the Washington State Ecosystem Conservation (WSEC) Program since 1991. These projects are done on a cost-share basis. The U.S. Fish and Wildlife Service (USFWS) pays for 30 percent, whereas other state, Federal, or private funds cover the remaining 70 percent. Agencies and local entities that have been involved are the U.S. Natural Resources Conservation Service (formerly the Soil Conservation Service), U.S. Forest Service, Washington Department of Fish and Wildlife, Washington Department of Ecology, various school districts, and the Audubon Society.

Project Goals/Objectives:

WSEC involves enhancement of fish and wildlife habitat on private lands in cooperation with landowners and other cooperators. Goals vary from project to project, but generally involve creating specific hydrologic or vegetation conditions. Likewise, ecological performance criteria are project specific, but these generally relate to vegetation communities and wildlife use of the project site.

Engineering Features:

WSEC projects have involved excavation, blasting, fencing, planting, dike construction, and channel construction.

Monitoring Techniques:

Monitoring is required for all WSEC projects. To date, monitoring has been conducted primarily by USFWS personnel. Standard techniques include photo monitoring, wildlife observations, and mapping. Monitoring entails at least one site visit per year. Each project has a separate monitoring plan that specifies monitoring techniques and schedules. For example, some projects involve transects for species survival, water quality measurements, sediment deposition measurements, and streambank stability. With the exception of projects involving planting or seeding,

most of the 100+ projects are meeting goals. The success of projects requiring revegetation has been mixed.

Cost Analysis:

Based on the 100+ projects that have been completed, engineering costs have been approximately 8 percent of total project costs. Labor costs, including administrative labor costs and monitoring costs, have accounted for approximately 50 percent of total expenditures. Materials costs, which include machine leasing, maintenance, equipment, and travel, amount to 42 percent of the total cost of a project. Maintenance is generally the responsibility of the landowner.

Sources:

Dave Kaumheimer, personal communication.

## Slip 5 Fisheries Mitigation Area, Washington

Point of Contact:

Mr. Richard Gilmur
Port of Tacoma
P.O. Box 1837
Tacoma, WA 98401-1837
Phone: (206) 838-0142

Project Description and Location:

Slip 5 is a triangular slip located on the face of the Blair-Sitcum Peninsula next to the Blair Waterway in Tacoma, Washington. The mitigation in Slip 5 was completed in the winter of 1987/1988. Prior to construction of the mitigation project, the shorelines were steeply sloped and riprapped at Slip 5, and the slope dropped off to form a deep basin.

Project Goals/Objectives:

To mitigate for the loss of juvenile salmonid habitat, which occured when Slip 2 and adjoining areas were filled, the Port of Tacoma built 2.7 acres of intertidal and shallow subtidal beach in Slip 5 (Jones & Stokes Associates, Inc. 1992).

Specific mitigation measures were developed during project review meetings involving the Port of Tacoma, Jones & Stokes Associates, and Federal, state, and tribal resource agency staff. During these meetings, the following ecological performance criteria were established in order to evaluate the success of the project:

1. Ninety percent of the mitigation habitat created must still exist at the end of the monitoring program (summer 1991).

2. The numbers of epibenthic organisms (prey for salmonids) collected at the mitigation area must be equal to those collected at Slip 2. Because Slip 2 has already been filled, and direct comparisons between the mitigation area and Slip 2 were not possible, comparisons were made using a reference site.

Engineering Features:

Construction of the mitigation beach required the partial filling of Slip 5 to decrease the slope of the shorelines and to increase the intertidal area. The beach was created by placing fill at the toe of the slope, and backfilling the area with clean dredge materials. A select substrate composed of a

variety of gravel sizes was placed over the fill materials to provide a substrate considered preferable for epibenthic organisms. The mitigation beach was built along the entire length of the western shore of Slip 5 and approximately one-half of the length of the eastern shore of Slip 5.

Several wave attenuation structures were also built in Slip 5 to protect the mitigation site from erosion. A rubble groin was constructed at the north end of the western shore. A piling baffle was built at the northern mitigation boundary of the eastern shore. There are two offshore piers in Slip 5 that lie parallel to the shores. Piling baffles interspersed with open spaces were placed along the face of each pier to further protect the shorelines from wave action.

Monitoring Techniques:

The original monitoring program specified physical monitoring in 1988 and 1989 and both physical and biological monitoring in 1990 and 1991. The Port of Tacoma added beach seining in 1988, and biological monitoring in 1989. Studies were conducted along the eastern and western beaches of the Slip 5 mitigation area and along the reference beach, which is located immediately off the end of the Milwaukee-Sitcum Peninsula. The reference beach is gently sloped and extends for several hundred feet into the bay. This site was selected as a reference site because it was one of the few sites not subject to development within the Port of Tacoma.

Physical monitoring consisted of beach topography surveys and surficial sediment surveys. Standard survey techniques were used to determine slopes and elevations in the Slip 5 mitigation beach. Diving surveys were conducted to determine the distribution and composition of overlying substrates. The biological portion of the monitoring program was designed to determine success or failure of the Slip 5 mitigation relative to densities of epibenthic organisms. Epibenthic samples were collected at low slack tide monthly between March and June, providing four sampling dates for each year of monitoring. On each sampling date, seven samples were collected along the +2-foot tidal elevation and seven samples along the -2-foot tidal elevation at both the western and eastern shore sites. Each sample was sorted to the lowest taxonomic/life history level and individual taxa were enumerated. Weekly (April-June) beach seine collections were also conducted between 1988 and 1991 to determine the extent to which juvenile salmonids used the mitigation beach.

Both success criteria were met or exceeded (Jones & Stokes Associates, Inc. 1992). Results of physical monitoring indicated that intertidal and shallow subtidal areas increased from 2.5 acres, following completion of construction in 1988, to 2.7 acres in 1991. Biological monitoring indicated that the density of epibenthic prey organisms at Slip 5 was nearly double the density of prey organisms collected from Slip 2 in 1987. The epibenthic community structure appeared to be dominated by organisms that juvenile salmonids typically eat. Chum and coho salmon use of the Slip 5 mitigation beach was also documented, but growth and residence times at the site are unknown.

Sources:

Jones & Stokes Associates, Inc. 1992. *Postproject Monitoring at Slip 5 Mitigation Area, 1991.* Final Report prepared by Jones & Stokes Associates, Inc. for Port of Tacoma, Tacoma, Washington.

## Broad Dyke Marsh Rehabilitation Project, Delaware

Point of Contact:

Mr. Robert Hossler
Delaware Division of Fish and Wildlife
250 Bear Road
Christiana, DE 19701-1041
Phone: (302)323-4492

Project Description, Location, and Goals/Objectives:

The Delaware Division of Fish and Wildlife is implementing a project to rehabilitate 210 acres of tidal freshwater wetlands. The goals of this project are the following:

- improve water quality
- reduce stormwater flooding
- increase biological diversity and improve wetland habitat
- improve recreational opportunities
- control mosquito populations
- control nuisance plant species
- provide educational opportunities.

An existing flood control structure only allows stormwater flow into the marsh area, causing continued degradation of the marsh. Removing this structure would cause severe flooding of upland areas. Therefore, the project will involve the installation of an automated water control structure, along with a 1,000-foot boardwalk and canoe launch, and various wildlife enhancement structures; implementation of a reed control program and a water management plan; and planting of beneficial plant species.

Engineering Features:

The engineering design was proposed in the fall of 1994, and construction is expected to begin in the spring of 1995. Engineering features will consist of the following:

- automated water control structure
- canoe launch
- duck boxes
- boardwalk
- vegetative planting
- reed control.

Most work will be conducted by state staff or volunteers. Physical alterations to the site are expected to include dredging, excavation of the existing dike and backfilling, and grading of the road and canoe launch. Initial concerns over the cultural value of the 17th-century dike were addressed when investigators determined that original portions of the dike that have been proposed for removal were actually destroyed and rebuilt in 1975.

Monitoring Techniques:

A variety of evaluation techniques will be developed once the construction phase is completed. Monitoring is expected to occur on an annual basis, with a final report to be developed after three years.

Cost Analysis:

This project featured the rehabilitation of 210 acres of tidal freshwater wetlands at a total cost of $776,000 (1995 dollars) (Table IV.2). This expenditure is primarily for materials, equipment, and supplies, since the volunteer and staff labor was not explicitly costed. The engineering design and hydrological study cost $36,000. Costs included $300,000 for a board walk to improve public access and $1,000 for a canoe launch area. Neither of these work elements was needed for the rehabilitation itself. Costs of the water control structure ($450,000) included $21,000 for dredging, $56,000 for evacuating a dike and backfilling, and the engineering study. Reed control cost $24,000 over 8 years. Four wildlife species were planted at the site in 1988-89 at a cost of $620. Monitoring is conducted annually, and there are periodic monitoring reports issued, but no cost estimate is available for the monitoring program.

TABLE IV.2. Cost by Component, Broad Dyke Marsh (estimate only; contract to be awarded)

| Project Component | Quantity | Unit | Equipment, Materials, Supplies, etc. | Labor | Total Costs ($1994) | Total Costs ($1995) |
|---|---|---|---|---|---|---|
| Automated water control structure[a] | 1 | LS | | | $438,959 | $450,000 |
| Canoe launch[b] | 1 | LS | | | $975 | $1,000 |
| Duck boxes | 31 | ea | | | $10 | $310 |
| Boardwalk | 1000 | lf | | | $292,639 | $300,000 |
| Reed control | 476 | acre | | | $23,653 | $24,248 |
| Wildlife planting | | LS | | | | $620 |
| **Total[c]** | | | | | **$756,236** | **$776,178** |

(a) Costs include $21,000 for dredging and $56,000 for evacuating dike and backfilling. Grading and canoe launch construction materials cost $1,000.

(b) The cost of grading and canoe launch does not include state staff labor. Most labor was volunteer or state staff; thus, uncosted or unavailable.

(c) No costs provided for annual maintenance, which consist of implementation of water management plan, electrical service, facilities, sensors, dike, culverts, gates, annual and weekly inspections, removal of trash and debris, and lubrication. No costs provided for 3-year annual monitoring program.

## Sources:

Project files from Robert Hossler.

## Doran Beach Marsh Enhancement Project, California

Point of Contact:

Dr. Robert Coats
Philip Williams & Associates, Ltd.
Pier 35, The Embarcadero
San Francisco, CA 94133
Phone: (415) 981-8363

Project Description, Location, and Goals/Objectives:

The project is located in Bodega Harbor near the town of Bodega Bay, California. The purpose of the project is to mitigate for the loss of wetland habitat in Sonoma, California. The general plan is to enhance existing salt marshes through reconnecting tidal hydrology to the sites (Site 1 and Site 2). In addition, a 6.5-acre pond area was constructed. Both sites are existing salt marshes that have been highly modified by alterations in hydrology as a result of dike and road construction. The overall project was expected to increase waterbird use, fish use of the marsh via channels, and habitat diversity.

Engineering Features:

The primary engineering features were as follows:

- remove the berm above Doran Beach Road culvert to provide tidal flushing action to the Site 2 marsh
- replace old culverts on the outer levee with new culvert and combination slide- and flap-gate outboard
- install a weir upstream in the existing tidal channel
- grade and excavate a new pond in the former alluvial fan located in the northeastern portion of the Site 1 marsh
- connect the pond by a channel to culverts and install a weir.

Monitoring Techniques:

Monitoring has consisted of visual observations of hydrology in the system and of marsh habitat development, and recordings of tide level. These observations have indicated that the marsh

is developing as expected. Hydrology has been as expected, although problems were encountered with weir boards during winter conditions.

Cost Analysis:

The total low bid price for this project was $237,750 in 1993 dollars ($243,731 in 1994 dollars), which included labor and materials, but not engineering, inspection, and monitoring. The project was completed in about 3 or 4 months.

Sources:

There are no published reports. Internal documents detail the conceptual design hydrologic modeling, construction specifications, and wetland and tidal hydrology monitoring results.

## Elk River Marsh Restoration, Washington

Point of Contact:

Dr. Robert Zeigler
Washington State Department of Fish and Wildlife
600 Capital Way North
Olympia, WA 98501-1091
Phone: (360) 902-2578

Project Description and Location:

In 1983, the Washington State Department of Wildlife (now Washington State Department of Fish and Wildlife [WDFW]) acquired a 57-acre parcel of land adjacent to the Elk River in Grays Harbor County, Washington. The site, formerly the upper portion of an extensive salt marsh on the southern shore of Grays Harbor estuary, was diked sometime early in the century for cattle grazing. The City of Ocean Shores, Washington, located on the northern shoreline of Grays Harbor estuary, offered the property as part of a mitigation settlement for filling of a 40+-acre tidal marsh for airport construction. In addition, the site was partial mitigation for an illegal fill of a tidal wetland at the eastern end of the estuary by ITT Rayonier. Restoration involved the reintroduction of tidal flushing to the system by breaching the dike. It was recognized that there had been dramatic land subsidence since the date of the dike's construction, and that recovery of the system to a natural state following dike breaching would not occur for at least a century.

Project Goals/Objectives:

The goal of the project was to achieve a stable and functioning salt marsh system that could be somewhat different from what had existed originally on the site. The pasture was dominated by the non-native reed canarygrass. The focus was to eliminate or severely restrict this nuisance species in the system by returning the system to tidal flushing and thereby increasing the salinity. At the time, this system represented the second largest dike-breach restoration in the Pacific Northwest (the largest was in Salmon River, Oregon).

Engineering Features:

The earthen dike, which was originally constructed of materials extracted from the marsh immediately adjacent to the dike, was breached in two places in 1987. The larger breach, approximately 50 feet wide, was located at the extreme northwest end of the seaward edge of the site, and connected the site to natural tidal channels in the existing salt marsh located immediately seaward of the dike. A much smaller breach was made approximately 150 feet to the southeast. Both

excavations were carried out with a standard backhoe. The entire system was allowed to develop naturally, with the exception of very limited plantings of Lyngby's sedge in a few areas by WDFW personnel.

Monitoring Techniques:

The site has been monitored annually since 1987 by WDFW, and more intensive surveys have also been conducted annually by Battelle since 1991. WDFW records the plant species occupying seven one-square-meter (1.196-square-yard) permanent quadrats placed along a transect that spans the site. In addition, it records observations on signs of wildlife use. Battelle records percentage cover of plant species within one-square-meter permanent quadrats spaced at 5- to 10-meter (5.47- to 10.94-yard) intervals along a 360-meter (393.84-yard) transect in the formerly diked marsh and along a 150-meter (164.1-yard) transect in an adjacent natural salt marsh. The latter control site represents conditions prior to diking.

The monitoring has shown that the site has shifted from a freshwater system to a salt marsh. Reed canarygrass has been virtually eliminated from the site, replaced by native salt marsh species (e.g., pickleweed, saltbush, and arrow-grass). The plant community remains in a state of relatively rapid change, even after seven years, and differs significantly from the control marsh. Aspects of the system that have increased are tidal hydrology, salinity, detritus flow, erosion, accretion, salt pan area, total wetland area, and use by waterfowl, shorebirds, otter, and fish. There is well-documented use by a number of wildlife species, such as elk and small mammals.

Cost Analysis:

Reported costs for the Elk River Marsh restoration project are $50,000 in 1987 dollars ($64,569 in 1994 dollars), including $25,000 for a 17-acre land purchase and $25,000 for dike breaching. Detailed costs for the restoration are not available. Expense for WDFW's monitoring is approximately $1,000 per year.

Sources:

Bennett, M. 1991. *Vegetation Establishment at Elk River Restoration Site: an Indicator of Successful Restoration.* Unpublished student report. Washington State Department of Wildlife, Olympia, Washington.

Correa, G. 1990. *Restoration of a Salt Marsh.* Unpublished student report. Washington State Department of Wildlife, Olympia, Washington.

Thom, R.M., and R. Zeigler. 1994. "Elk River Salt Marsh Restoration." In *Partnerships & Opportunities in Wetland Restoration*, M. Martz, A. Jarvela, K. Kunz, C. Simenstad, F. Weinmann, eds., pp. 97-98. EPA 910/R-94-003, U.S. Environmental Protection Agency, Seattle, Washington.

## Gog-Le-Hi-Te Wetland Restoration, Washington

Point of Contact:

Dr. Ronald M. Thom
Battelle/Marine Sciences Laboratory
1529 West Sequim Bay Road
Sequim, WA 98382
Phone: (360) 681-3657

Project Description and Location:

In 1985 and 1986, the Port of Tacoma restored, by excavating and grading, a 9.6-acre wetland in the Puyallup River Estuary, Tacoma, Washington. The Gog-Le-Hi-Te wetland was restored on the former site of a solid-waste landfill to mitigate for habitat lost 1 mile downstream at the 9.6-acre Parcel 5 wetland, which was filled for development. Gog-Le-Hi-Te is located at the upstream extent of salinity intrusion in the tidally influenced portion of the Puyallup River. In accordance with criteria established in negotiation with state and Federal resource agencies, 50 percent of the habitat area was designed to support juvenile salmon, 20 percent waterfowl, 10 percent shorebirds, 10 percent raptors, and 10 percent small mammals. The Gog-Le-Hi-Te wetland is a persistent, emergent wetland within an intertidal estuarine system. In its present state of development, the restored wetland complex is a regularly flooded, brackish wetland system consisting of tidal channels, mudflats, a transplanted sedge marsh, a cattail marsh, a shrub-scrub swamp, riparian hardwoods, and an upland grassland. At the time it was restored, the Gog-Le-Hi-Te wetland was the largest estuarine mitigation project in the state of Washington. The wetland was designated as a west coast demonstration site for wetland restoration by the Corps Waterways Experiment Station (WES), under its Wetland Demonstration Program. During the last century, 98.6 percent of the wetland habitat present in the Puyallup River estuary has been destroyed through dredging, diking, and filling. Wetlands that remain are extremely small, fragmented, and often contaminated with industrial and domestic wastes. Along 46 miles of the Puyallup River, Gog-Le-Hi-Te wetland represents one of the only emergent marsh habitats available for temporary residence or foraging of outmigrating juvenile salmon.

Engineering Features:

Excavation and river dike construction commenced in early July 1985. A pocket of polychlorinated biphenyls (PCBs) was discovered during excavation and had to be removed, delaying breaching of the dike and tidal inundation. The river dike was breached on February 20, 1986, following excavation of approximately 72,000 cubic yards of solid waste landfill and river and mudflat sediments (to reach the original marsh surface), rerouting of a gas pipeline unearthed during the excavation, construction of a flood control dike, and contouring of the new wetland topography to conform to the habitat requirements of the desired vegetation. A total of 48,800 culms (individuals)

of the Lyngby's sedge was successfully transplanted onto the mudflats between March 1986 and May 1987.

Monitoring Techniques:

Over the first seven years of its development, the Gog-Le-Hi-Te wetland's functional attributes have been assessed by researchers. Basic assessment parameters were the following: 1) topographic, sediment, and vegetative structure; 2) water chemistry and temperature; 3) survival, distribution, and growth of the planted sedge and naturally recruited emergent plants; 4) benthic and planktonic invertebrate assemblage composition and standing stock; and 5) fish and bird species occurrence and density (Simenstad and Thom 1994). Because monitoring data of fish occurrence and abundance were considered to be poor measures of the actual benefit derived from fish occupancy of the wetland, dedicated experiments to determine juvenile salmon residence time, foraging, and growth were performed (Shreffler et al. 1990, 1992).

Within only a few years, as many as six attributes of wetland function displayed rapid development and equivalency to reference or literature documentation (Simenstad and Thom 1994). The most rapid response by any organisms was the immediate occupation of the wetland complex by diverse assemblages of birds. Almost 70 percent (80) of the 112 species documented by 1990 were observed in the wetland in the first year of its development. Residence time (1 day to 9 days for chum, 1 day to 43 days for chinook), prey composition (chironomid larvae and pupae, plecopterans, and adult dipterans) and growth (5.2 milligrams/day for chinook) of juvenile chum and chinook salmon were comparable to that in the meager literature from natural estuarine systems (Shreffler et al. 1990, 1992). Taxa richness of epibenthic organisms and fishes and fish densities all approached asymptotic trajectories, and three indicators of bird usage approximated quadratic trajectory forms, providing almost instantaneous function. However, many parameters indicative of other ecological functions indicate that Gog-Le-Hi-Te is still in an early stage of development or on a pathway different from that of comparable brackish wetland communities in this region. Although this project is often described as one of the most "successful" estuarine restoration projects in the Pacific Northwest, Simenstad and Thom (1994) cautioned that researchers still lack the scientific basis to affirm that functional equivalency trajectories can be used as measures of wetland ecosystem development and mitigation/restoration "success." Applied studies of wetland restoration and creation need to be integrated with long-term basic ecological studies of ecosystem succession and disturbance.

Cost Analysis:

Detailed costs are not available. Approximate costs provided by the Port of Tacoma were as follows:

| | $1986 | $1994 |
|---|---|---|
| Surveys and design | $250,000 | $334,623 |
| Pipeline relocation | $200,000 | $267,701 |
| Excavation | $700,000 | $936,953 |
| Fill | $200,000 | $267,701 |
| Removal and disposal of contaminated material | $300,000 | $401,551 |
| Riprap | $170,000 | $227,546 |
| Miscellaneous (permits, specifications, etc.) | $750,000 | $1,003,878 |
| Maintenance monitoring | $300,000 | $401,551 |
| Approximate Total | $2,870,000 | $3,841,504 |

Sources:

Simenstad, C.A., and R.M. Thom. 1994. "Functional Equivalency of Restored Estuarine Wetlands: Temporal Patterns in Equivalency Trajectories of the Gog-Le-Hi-Te Wetland." *Ecological Applications* (in press).

Shreffler, D.K., C.A. Simenstad, and R.M. Thom. 1992. "Juvenile Salmon Foraging in a Restored Estuarine Wetland." *Estuaries* 15:204-213.

Shreffler, D.K. C.A. Simenstad, and R.M. Thom. 1990. "Temporary Residence by Juvenile Salmon in a Restored Estuarine Wetland." *Canadian Journal of Fisheries and Aquatic Sciences* 47:2079-2084.

## Palo Alto Harbor Improvements/Marsh Restoration, California

Point of Contact:

Mr. Jim Harrington
City of Palo Alto, Public Works Engineering
250 Hamilton Avenue
Palo Alto, CA 94301
Phone: (415) 329-2693

Project Description, Location, and Goals/Objectives:

The Harbor Improvement Project in Palo Alto, California, consists of 4.5 acres of marsh restoration, in addition to public access and picnic area improvements, construction of a new sailing station for hand-carried boats, and restoration of the Harbormaster's cottage. The project goals were to meet the San Francisco Bay Conservation and Development Commission (BCDC) permit conditions and to provide habitat for several endangered and threatened species that exist in tidal salt marshes.

Engineering Features:

Work on the Harbor Improvement Project began in late 1992 and was substantially completed in December 1993. All improvements are now operational and available to the public. The project involved excavating four acres of land at the southern tip of Harbor Point. Foraging areas were created for the endangered clapper rail by excavating low channel areas below mean high tide. A marsh plain was also excavated to provide pickleweed habitat for the clapper rails and salt marsh harvest mouse. Suitable native buffer plants were planted as a barrier to protect intrusion into the sensitive marsh habitat. The project includes over 1,700 feet of bicycle and pedestrian paths, three interpretive observation stations, four vista points with seven benches, and 1,500 feet of bollard and cable fencing.

Monitoring Techniques:

No monitoring was conducted or is planned.

Cost Analysis:

The total cost of the Palo Alto marsh restoration project is $594,476 (1992 dollars) (Table IV.3). Costs include the direct costs of marsh restoration, public access improvements, sailing station construction, Harbor Master's cottage restoration, and picnic area construction. Construction costs equal $429,475. This contract bid is 31 percent below the engineer's estimate of $621,734. The

difference in estimates is a result of higher engineer-estimated costs for demolition, earthwork, stockpile embankment, asphalt concrete berm, bollards, buffer plant installation, and day maintenance. It is interesting to note, however, that the chosen contractor estimated higher costs for retaining wall and handrail construction, topsoil installation, and marsh plant installation. All the cost components listed for this project are installed costs including labor, materials, and equipment. Design costs for the project equal $165,000.

TABLE IV.3. Cost by Component, Palo Alto Harbor

| Project Component | Quantity | Unit | Equipment, Materials, Supplies, etc. | Labor | Total Costs ($1994) | Total Costs ($1992) |
|---|---|---|---|---|---|---|
| Mobilization | | LS | $11,400 | N/A | $11,920 | $11,400 |
| Demolition (includes launch ramp) | | LS | $15,000 | | $15,684 | $15,000 |
| Clearing and grubbing | | LS | $10,000 | | $10,456 | $10,000 |
| Earthwork | 49,422 | cy | $197,688 | | $206,706 | $197,688 |
| Stock pile embankment | 49,422 | cy | $45,962 | | $48,059 | $45,962 |
| 2-inch decomposed granite on 4-foot aggregate base | 14,540 | sq ft | $12,504 | | $13,074 | $12,504 |
| 2-inch AC on 6-foot aggregate base | 1,320 | sq ft | $6,600 | | $6,901 | $6,600 |
| Asphalt concrete berm | 130 | lf | $390 | | $408 | $390 |
| Retaining wall and handrail | 140 | lf | $32,739 | | $34,232 | $32,739 |
| Retaining wall | 124 | lf | $19,518 | | $20,408 | $19,518 |
| Bollards | 98 | ea | $5,880 | | $6,148 | $5,880 |
| Cable | 1,520 | lf | $3,040 | | $3,179 | $3,040 |
| Detail striping | 50 | lf | $50 | | $52 | $50 |
| 12-inch solid line | 50 | lf | $50 | | $52 | $50 |
| Pavement marking | 4 | ea | $50 | | $52 | $50 |
| Directional sign | 1 | ea | $2,000 | | $2,091 | $2,000 |
| Park bench (double) | 3 | ea | $2,723 | | $2,847 | $2,723 |
| Park bench (single) | 7 | ea | $3,086 | | $3,227 | $3,086 |
| Bike rack bollard | 6 | ea | $480 | | $502 | $480 |
| Trash receptacle | 7 | ea | $6,523 | | $6,820 | $6,523 |
| Irrigation system | | LS | $5,500 | | $5,751 | $5,500 |
| Topsoil, plain | 102 | cy | $3,500 | | $3,660 | $3,500 |
| Topsoil, mix | 370 | cy | $12,765 | | $13,347 | $12,765 |
| Weed control rings | 903 | ea | $1,806 | | $1,888 | $1,806 |
| Buffer plants | 903 | ea | $3,928 | | $4,107 | $3,928 |
| Marsh plants (cord grass) | 1,590 | ea | $14,310 | | $14,963 | $14,310 |
| Marsh plants (gumweed) | 392 | ea | $1,568 | | $1,640 | $1,568 |
| Disking | 17,327 | sq yd | $2,946 | | $3,080 | $2,946 |
| Hydroseeding | 0.23 | acre | $0 | | $0 | $0 |
| Siltfence | 1,990 | lf | $5,970 | | $6,242 | $5,970 |
| Maintenance | | LS | $1,500 | | $1,568 | $1,500 |
| Design | | LS | $165,000 | | $172,527 | $165,000 |
| **Total** | | | **$594,476** | | **$621,591** | **$594,476** |

Sources:

Project files and personal communication with Jim Harrington.

**Salmon River Estuary Restoration, Oregon**

Point of Contact:

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Project Description and Location:

In 1974, Congress designated 8,400 acres in Oregon's Siuslaw National Forest, including the Salmon River Estuary, as the Cascade Head Scenic-Research Area. The long-term goal for the estuary was to restore it to its condition prior to diking and agricultural use. In Oregon, and the Pacific Northwest in general, diking to create agricultural land was one of the major causes of historic marsh loss. The alternative strategies that were considered for restoring the Salmon River Estuary to natural conditions were complete dike removal and partial dike removal. Complete dike removal was chosen because of aesthetics and because it was considered to have the best chance of achieving the overall goal of full restoration of the estuary to predisturbance conditions (Frenkel and Morlan 1990).

The Salmon River Estuary project involved the restoration of approximately 208 acres of diked pasture to salt marsh by simply removing the dike and reconnecting tidal creeks to the estuary (Morlan and Frenkel 1992). The restoration project occurred in two separate steps: 1) a dike enclosing a 52-acre pasture on the north side of the Salmon River was removed and tidal creeks were reconnected to the estuary in 1978, and 2) a dike enclosing a 156-acre pasture on the south side of the Salmon River was removed in 1987.

Project Goals/Objectives:

No ecological performance criteria were formally stated; however, composition and structure of the restored vegetation was assumed to reflect success. Undiked "control" marshes were used to judge success by comparative analysis. Oregon State University, U.S. Forest Service, and U.S. Environmental Protection Agency (EPA) Region 10 were the principal agencies involved in this project. The restoration effort was funded entirely by the U.S. Forest Service. This project is viewed as one of the most successful examples of estuarine restoration in the Pacific Northwest, in part because restoration (reflected by resulting composition and structure of the vegetation) involved relatively little intense manipulation.

Engineering Features:

There were no physical structures built for this project. Dike removal in 1978 and 1987 was the primary alterations to the site. No grading, planting, or other "active" restoration activity was conducted.

Monitoring Techniques:

Vegetation surveys conducted prior to dike removal, showed that the site, which had been diked for 17 years, was dominated by pasture species, including common velvetgrass, Pacific silverweed, and bentgrass (Frenkel and Morlan 1990). The site had also subsided by 12 to 16 inches relative to surrounding undiked high salt marsh. Former tidal creeks were partially filled due to livestock trampling the banks.

A detailed two-year baseline study followed by eight years of subsequent monitoring allowed researchers to evaluate recovery of the ecosystem over a 10-year period (Frenkel and Morlan 1990). Empirical field work was used for monitoring. The parameters that were monitored were the vegetation composition change in about 120 permanent plots and about 350 nonpermanent plots, biomass harvest, elevation, salinity, soil texture, and sediment accretion. The frequency of monitoring was as follows: once in 1977 predike breach on north side; annually, 1984, 1988, 1992, on north side; and annually, 1987-1993, on south side. The methods for assessing performance of the system were very effective for vegetation. Fisheries and avian surveys were not conducted; therefore, there is a lack of critical information for a full assessment of the functioning of the system.

Following restoration of tidal influence, there was a rapid die-off of pasture species, and bare flats were rapidly revegetated by colonizing salt marsh species brought in by the tides. Two groups of colonizers were distinguished: 1) ephemeral species such as saltmarsh sandspurry, dwarf alkaligrass, and brass buttons were initially abundant, but disappeared completely by 1988; and 2) persistent native colonizers, principally pickleweed, Lyngby's sedge, and saltgrass, replaced the ephemeral colonizers and comprised 91 percent of the cover by 1988. Analysis of soil cores indicated that the lower marsh surface elevation is recovering by a combination of sedimentation, accumulation of organic material, and soil swelling. Original high marsh plant communities have not redeveloped. These results suggest that potential vegetation at a salt marsh restoration site can be reasonably well predicted by considering tidal elevation, salinity, soil texture, and proximity to propagules. Ten years after dike removal, primary productivity of the salt marsh--a measure of ecosystem functional recovery--was 4.3 pounds/square yard/year. The rate at which energy is incorporated into this marsh is almost twice that of the diked pasture and of adjacent, unaltered salt marshes, and is typical of a young, disturbed ecosystem (Morlan and Frenkel 1992).

Monitoring studies to date indicate that the diked pasture has been successfully restored to a functioning salt marsh system (Morlan and Frenkel 1992). However, it is clear that the recovering salt marsh clearly differs from the "predisturbance" system in terms of elevation and hydrology. The

lowering of the marsh surface elevation as a result of diking has had a major effect on plant community recovery and the hydrology of the system. Morlan and Frenkel (1992) concluded on the basis of the first 10 years of monitoring data that full recovery from subsidence would take five decades or more. A volunteer monitoring effort is ongoing.

Cost Analysis:

The total cost of the Salmon River Estuary restoration project is $61,500 (1987 dollars) (Table IV.4). Costs include the direct cost of dike removal, administration, and monitoring (1987 to 1993). The YWCA Dike (6,000 feet), which has two tidal gates, was removed for $18,000 (not including monitoring), a unit cost of $3.00 per foot. The Basin Lands Dike (2,600 feet) was removed for $5,500 (not including monitoring), a unit cost of $2.12 per foot. The cost of both projects, which is reported as "equipment costs," includes labor and materials. The YWCA Dike removal costs include rental of an excavator, a bulldozer, two dump trucks and three to four laborers' time for a period of 13 days. The Basin Lands Dike removal costs include rental of an excavator and three to four laborers' time for a period of five days. Unlike the YWCA project costs, those of the Basin Lands Dike removal include contract administration.

TABLE IV.4. Cost by Component, Salmon River

| Project Component | Quantity | Unit | Equipment, Materials, Supplies, etc. | Labor | Total Costs ($1994) | Total Costs ($1987) |
|---|---|---|---|---|---|---|
| YWCA dike removal | 6,000 | lf | $16,000 | | $20,662 | $16,000 |
| Contract administration | | LS | $900 | | $1,162 | $900 |
| Lands administration | | LS | $1,100 | | $1,421 | $1,100 |
| Subtotal | | | $18,000 | | $23,245 | $18,000 |
| Basin Lands dike removal | 2,600 | lf | $5,000 | | $6,457 | $5,000 |
| Lands administration | | LS | $500 | | $646 | $500 |
| Subtotal | | | $5,500 | | $7,103 | $5,500 |
| Monitoring | | LS | $38,000 | | $49,072 | $38,000 |
| **Total** | | | **$61,500** | | **$79,420** | **$61,500** |

Sources:

Frenkel, B.E., and J.C. Morlan. 1990. *Restoration of the Salmon River Salt Marshes: Retrospect and Prospect.* Final report to the U.S. Environmental Protection Agency, Region 10, Seattle, Washington.

Morlan, J.C., and B.E. Frenkel. 1992. "The Salmon River Estuary." *Restoration & Management Notes* 10(1): 21-23.

**Spencer Island Wetland Restoration and Wildlife Enhancement, Washington**

Point of Contact:

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Project Description and Location:

Spencer Island is located in northern Puget Sound, Snohomish County, near Everett, Washington. The island was diked in the late 1800s and converted to agricultural use. The dike around the perimeter of the island prevented two tidally influenced sloughs from flooding the interior of the island. However, many tide gates allowed sufficient water on the island to create palustrine wetland conditions. Inside the dike, the habitat was dominated by marsh containing dense monotypic stands of reed canarygrass. Lower, wetter areas were dominated by cattails and soft rush. Higher areas of the island graded from scrub-shrub wetlands with blackberry and wild rose to forested areas with mixed stands of alder, willow, black cottonwood, and Sitka spruce. These existing habitats supported a variety of wildlife, including pileated woodpecker, marsh wren, quail, raptors, shorebirds, and waterfowl, as well as deer, coyote, and a variety of small mammals (Tanner 1993). Approximately 10 to 15 acres on the north and south ends of the island were outside the dike. The southern undiked area was characterized as a tidal swamp, dominated by Sitka spruce, alder, and a dense shrub understory. The northern undiked area was described as a brackish intertidal marsh, dominated by bulrush, cattail, and scattered patches of sedge along the edges of the two sloughs.

In 1989, the 414-acre island was purchased by Snohomish County and WDFW and taken out of agricultural use. The Spencer Island wetland restoration and enhancement project was composed of two main elements: 1) portions of southern Spencer Island were restored to tidal influence by breaching the exterior dike in three places, and a cross levee was constructed between the northern and southern portions of the island to prevent tidal inundation of the entire island, restricting daily flooding to approximately 50 acres in the southern portion of the island; and 2) water control structures were built into the cross levee to allow for palustrine wetland enhancement on the northern portion of Spencer Island.

Project Goals/Objectives:

This noncompensatory habitat restoration and enhancement project was developed to advance knowledge of restoration techniques, to benefit local ecology, and to establish the basis for a larger watershed-based restoration program. Local agencies and entities involved in this project were the

Puget Sound Estuary Program Management Committee, EPA, USFWS, the Washington Department of Ecology, WDFW, and Snohomish County Parks and Recreation Department.

<u>Engineering Features</u>:

The largest single element of this project from an engineering design, cost, and permitting perspective was the construction of a cross levee to restrict tidal inundation to the southern portion of the island. This structure was designed to prevent extreme water surface fluctuations in the northern areas currently managed for waterfowl nesting. After the cross levee was constructed in summer 1994, the exterior dike on the southern portion of the island was breached in three places in fall 1994. Using computer models of hydraulic conditions in the adjacent sloughs, the breaches were designed to allow for complete flooding and drainage on each tide cycle, fish access, and water velocities slow enough to prevent erosion of the exterior dike during tidal exchange.

Enhancement of the northern portion of the island involved building water control structures into the cross levee to allow for greater control of water levels. Water levels will be managed for waterfowl production, reed canarygrass control, and water quality benefits, and it will vary with season. To increase waterfowl production, approximately 30 nesting islands will be created along each side of the main drainage ditch. Two areas at elevations of 9.1 to 10.1 feet relative to mean lower low water (MLLW) will be revegetated with native shrubs and trees.

<u>Monitoring Techniques</u>:

In November 1992, prior to project implementation, the Washington Department of Ecology, WDFW, EPA, Snohomish County, and USFWS completed a HEP analysis of wildlife habitat values for the north and south portion of Spencer Island. Models selected for this analysis were as follows: 1) red tailed hawk, 2) belted kingfisher, 3) mallard, 4) wood duck, 5) great blue heron, and 6) muskrat. Wetland functions were also assessed using WET. The analysis addressed groundwater function, floodflow buffering function, sediment retention, nutrient removal/transformation functions, production export, wildlife breeding habitat, wildlife migration habitat, and aquatic diversity and abundance.

To assess the results of the restoration project, a long-term (5- to 10-year) monitoring program is presently being undertaken on Spencer Island. Specific monitoring protocols have been established to satisfy ecological and programmatic performance goals established for the restoration site. The major elements of the proposed monitoring program and the associated performance indicators are summarized below:

- <u>Tide gauge monitoring (south island)</u>: ensure that normal tidal fluctuations are reestablished to 50 acres of the southern portion of the island

- Current velocity monitoring (south): document that current velocity/head differences are not excessive in the tidally restored southern portion of the island

- Aerial photograph analysis (south and north): for south island, ensure that 50 acres of south island are tidally inundated and that the restored habitat resembles typical tidal marsh geomorphology; provide increased habitat diversity; provide increased fish access; for north island, provide increased structural diversity and improved food resources for waterfowl and increased overwintering/migratory habitat quality

- Elevation surveys (south and north): for south island, ensure that 50 acres of south island are tidally inundated; provide increased structural diversity; for north island, provide a stable hydrologic regime and increased open water area for waterfowl

- Vegetation biomass (south and north): for south island, document a decrease in the area of monotypic reed canarygrass and an increase in intertidal habitat communities; for north island, provide increased structural diversity and increased overwintering/migratory habitat quality

- Forest community survey (south): document a decrease in area of monotypic reed canarygrass and an increase in intertidal habitat communities

- Waterfowl survey (south and north): for south island, document increased species diversity of waterfowl; for north island, document increased waterfowl use

- Water quality (south and north): document improved water quality, including temperature, dissolved oxygen, conductivity, and turbidity

- Fish prey resources (south): provide an increase in prey resources for juvenile salmon

- Fish use (south and north): for south island, document an increase in fish access and species diversity; for north island, document increased access to available habitat.

Cost Analysis:

The total cost of the Spencer Island wetland restoration project is reported to be $762,030 (1994 dollars) (Table IV.5). Costs include the construction of a cross levee and three bridges, installation of culverts, and breach work. The cross levee construction costs are $128,000 for the original construction bid; $20,943 for a change order; $30,000 for quantity overruns; $46,000 for project administration; $35,000 for design, engineering and planning; and $7,418 for permits. The culvert installation and breach work costs are $144,402 for change orders (culvert assistance and breach excavation); $10,000 for force account (culvert repair); $10,000 for quantity overrun; $45,808 for project administration; $12,250 for design, engineering and planning; $33,278 for materials (48-

inch, 36-inch-diameter culverts, temporary culvert covers, 20-foot by 24-inch plastic culverts, 48-inch by 40-foot replacement culvert, and 40-foot pipe, band, gasket); \$6,051 for excavator rental; and \$11,487 for permits. Bridge construction costs are \$10,000 for force account (bridge assistance); \$62,549 for design, engineering, planning, and administration; \$19,244 for construction of Bridge #1; \$20,044 for construction of Bridge #3; \$110,155 for Bridge #2 (including \$9,086 for extra piles and \$90,000 for 250-foot bridge construction bid estimate - contractor not yet selected); and \$9,402 for materials (recycled plastic, pile wrap, and ultrasonic testing of steel girders).

TABLE IV.5. Cost by Component, Spencer Island

| Project Component | Quantity | Unit | Equipment, Materials, Supplies, etc. | Labor | Total Costs ($1994) |
|---|---|---|---|---|---|
| Cross levee | | LS | $267,361 | | $267,361 |
| Culverts/breaches | | LS | $263,276 | | $263,276 |
| Bridges | 3 | LS | $231,393 | | $231,393 |
| **Total** | | | $762,030 | | **$762,030** |

Sources:

Tanner, C.D. 1993. *Spencer Island Wetland Restoration and Enhancement Report.* Prepared for Snohomish County Departments of Parks and Recreation and Public Works, Washington State Departments of Ecology and Fish and Wildlife and U.S. Environmental Protection Agency by U.S. Fish and Wildlife Service, Olympia, Washington.

## Prairie Creek Fish and Wildlife Habitat Enhancement Project, California

Point of Contact:

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Project Description and Location:

The project area is located within an operating dairy ranch in Humboldt County, two miles upstream of Prairie Creek's confluence with Redwood Creek, near Orick, California. From 1983 to 1985, a one-mile reach of Prairie Creek was treated to control streambank erosion and to restore riparian vegetation. Different bank stabilization methods were used on a total length of 2,200 feet of streambank. Fencing was installed 10 to 12 feet from the streambank edge along the entire reach (8,700 feet) to prevent livestock from entering the project area. The area between the fence and the water's edge was planted with a variety of native riparian plants.

Project Goals/Objectives:

The overall enhancement plan was based on the following considerations: 1) restoration of high-quality instream and riparian habitat, 2) cost-effectiveness and physical effectiveness of bank stabilization techniques, 3) protection of livestock pasture, and 4) dairy farm management needs.

Engineering Features:

The project design included a variety of bank stabilization techniques, a fencing pattern that includes livestock watering and stream crossing accesses, and a riparian restoration zone 10 to 12 feet wide along each streambank. Specific streambank stabilization techniques developed for this project were as follows:

- rock riprap with willow mattresses
- tree and limb deflectors
- willow frames
- brush bundles

- post and wire fence revetment

- willow terraces.

Riparian corridor fencing consisted of five strands of 12.5-gauge barbed wire secured to heavy-duty 7-foot metal posts. Split, 4-by-5-inch redwood posts, 7 feet long, were set and braced every 100 feet or at every bend. In addition, 900 feet of willow fence was constructed along the base of the streambank parallel to the main barbed wire fence. The willow fence was connected to the main fence at one end, and the other end was located at a deep pool or steep bank where livestock would find passage difficult or impossible.

Over 7,000 seedlings and willow sprigs were planted within the fenced corridor. The species planted were two-year-old red alder, big leaf maple, Douglas fir, Sitka spruce, coast redwood, and willow cuttings from onsite vegetation.

Monitoring Techniques:

After two years of monitoring, all sites where rock riprap with willow mattresses was used were observed to have held completely, and there was no erosion observed at these sites. Tree and limb deflectors also proved to be an effective form of erosion control and had the added benefit of providing instream cover that was used quickly and extensively by fry and adult steelhead and salmon. Willow frames worked well at two sites, but failed at another because the slope toe was not protected and because of beaver browsing. This technique would be more successful if rock riprap were used along the toe of the slope. Brush bundles were ineffective, and bank failure occurred during the first winter. Post and fence wire revetment performed very well with no failure. The willow terraces held for one year during high flows, but then gradually failed entirely as an eddy increased its cutting force during lower spring flows.

Livestock and flood damage to the fencing was minimal. Limited damage was caused by elk as they jumped the fence and broke wires. Use of the best materials available for all fencing components minimized long-term maintenance needs.

Overall survival of all plant species was 70-75 percent after two years. Elk browse damage was low. Planting two- to three-year-old trees that were at least two feet tall helped to ensure that the trees overtop and outcompete the natural grass cover.

Cost Analysis:

The total cost of the Prairie Creek project is $76,660 (1985 dollars) (Table IV.6). Project costs consist of labor (supervisory, field, and other), materials (general and final report and atlas), equipment, transportation, signage, and administration. Transportation, signage, and administration are reported here as "other." A one-mile reach of the creek was treated to control streamside erosion

and to restore riparian vegetation. Several different methods were used over a total length of 2,200 feet. Per unit costs for these various techniques (based on total cost of labor, materials, equipment rental, and transportation) include the following:

| | |
|---|---|
| Tree limb deflector | \$1.40 - \$1.65/square foot |
| Willow frames | \$2.00 - \$2.25/square foot |
| Post and wire fence revetment | \$1.40 - \$1.65/square foot |
| Rock riprap and brush mattress | \$3.75 - \$4.00/square foot |
| Willow terraces | \$1.50 - \$1.75/square foot |
| Willow frames and rock riprap | \$3.10 - \$3.35/square foot |

The average cost for erosion control work at Prairie Creek was between \$2.25 to \$3.00 per square foot. In addition, fencing was installed 10 to 12 feet from the streambank edge along the entire reach to prevent livestock from entering the project area. The area between the fence and water's edge was planted with a variety of native riparian plants. Cost estimates for these components of the project were not reported separately.

TABLE IV.6. Cost by Component, Prairie Creek

| Project Component | Quantity | Unit | Equipment, Materials, Supplies, etc. | Labor | Total Costs (\$1994) | Total Costs (\$1985) |
|---|---|---|---|---|---|---|
| Erosion control, fencing, and revegetation | | LS | \$44,303 | \$32,214 | \$104,525 | \$76,666 |
| **Total** | | | **\$44,303** | **\$32,214** | **\$104,525** | **\$76,666** |

Sources:

Schwabe, J. 1986. *Prairie Creek Fish and Wildlife Habitat Improvement Project.* Final Report prepared for California State Coastal Conservancy by Redwood Community Action Agency, Eureka, California.

## McDonald Creek Restoration Project, California

Point of Contact:

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Project Description and Location:

McDonald Creek is located in Humboldt County, 6.5 miles south of the town of Orick, California. It is a third-order stream, which is a tributary to Stone Lagoon. The primary activities that have caused habitat degradation in McDonald Creek and Stone Lagoon are logging, road construction, and livestock grazing. These activities resulted in loss of riparian vegetation, creation of barriers to salmonid migration, sedimentation of salmon spawning and rearing habitat, and accelerated sedimentation of Stone Lagoon.

Project Goals/Objectives:

This restoration project had two main objectives: 1) reduce sediment input by treating streamside erosion problems, and 2) improve spawning and rearing habitat for cutthroat and steelhead by installing log weirs in a 400-foot section of the main stem of McDonald Creek, and by installing instream structures at other sites lacking in structure. Previous watershed restoration efforts in the McDonald Creek watershed began in 1979 and focused on improving habitat in the anadromous zone of McDonald Creek by reducing sediment input from failing road crossings and streambank erosion, planting native species within the riparian corridor, and placing habitat enhancement structures in the creek. Since the late 1980s, fish rearing projects by Redwood Community Action Agency, Humboldt State University, and California Department of Fish and Game have attempted to maintain and increase the native coastal cutthroat trout, a species of special concern in California.

Engineering Features:

The project was initiated in June 1993 and involved removal of an old, failing road crossing composed of large redwood logs, which were then used to armor both right and left streambanks downstream that were eroding as a result of the crossing's failure. Three silt fences were constructed downstream from the project site. Fill (3 cubic yards) from the top of the bridge was removed by hand to reveal 14 redwood logs that composed the bridge. The logs were removed and grip-hoisted into place along the streambanks below. On the left bank, a three-tiered, L-shaped retaining wall was constructed using cabled dead-men, rebar pins, and culvert stakes to secure the structure. On the

right bank, the remaining logs were placed into hand-excavated toe trenches and pinned with rebar. Approximately 250 native conifers and hardwood were planted at the site the following winter. Another section of the streambank was riprapped with 6 cubic yards of 1- to 3-foot rock. Smaller rock was then hand-chinked between the larger rock. All disturbed soil areas were seeded with grass, and conifers were planted along the top of the bank the following winter.

A total of seven instream structures were installed on this project at six different sites. Six structures are located in a 400-foot section of the main channel just upstream of the riprapped bank. The seventh structure was installed on the north fork of McDonald Creek at the Redwood Trails Campground. These seven structures were as follows:

- Site 1: double wing deflector
- Sites 2 and 5: digger logs
- Sites 3 and 4: high profile digger logs
- Site 6: redwood baffles.

All disturbed areas resulting from the placement of these structures were straw mulched and later planted with a total of approximately 150 native conifers and hardwoods.

Monitoring Techniques:

Observations over the winter of 1993-1994 indicated that both streamside erosion sites had successfully retained sediment sources. Survival rate of trees planted onsite was approximately 95 percent. All areas of previous soil disturbance had begun to effectively revegetate voluntarily. The instream log structures all appeared to be well secured after one winter season. At Site 1, the double wing deflector formed a midchannel scour pool at the thälweg, as predicted. The structures at Sites 2, 3, 4, and 5 provided beneficial habitat cover over the channel, but had not, after only one winter, promoted much scouring. Collectively, the survival rate of trees on these sites was about 85 percent. The work done on this project, combined with the other work done in the watershed in the past, has greatly improved cutthroat and steelhead habitat in McDonald Creek. Continued efforts to monitor fish populations will be valuable for tracking future success of the habitat improvements.

Since 1992, Humboldt State University (HSU) studies of the Stone Lagoon and McDonald Creek have focused on growth of cutthroat trout in Stone Lagoon, nonsalmonid fishes in Stone Lagoon, limnology of the Lagoon, and spawning and migration habits of salmonids in McDonald Creek. Seining the lagoon to identify fish species has revealed a rich food base in the lagoon. Since the winter of 1992, HSU has operated a weir and fish trap to sample upstream and downstream migration during the cutthroat spawning runs.

Cost Analysis:

The total cost of the McDonald Creek 1993 stream restoration project is $78,007 (1990 dollars) (Table IV.7). $54,500 was awarded by California Department of Fish and Game and Wildlife Conservation Board for this project. Costs include the direct costs of the installation of two erosion control structures and six instream structures. Labor costs for bank erosion control structures are based on 2,928 hours of work with an average hourly rate of $13 and 35 percent staff benefits. Construction material costs consist of $200 for fence stakes, $1,750 for cable and clamps, $400 for culvert stakes, and $300 for rebar. Supply costs are $500-worth of tools and instruments (grip hoist repairs, mainline, and miscellaneous hand tools), alders, and gloves. Equipment costs include $230 for tool rental. Other operating expenses are $600 for transportation costs, $50 for fuel, $40 for photographic supplies, $20 for printing and duplicating, $410 for insurance, and $6,181 for administrative overhead.

Labor costs for instream structure installation are based on 1,480 hours of work with an average hourly rate of $13 and 35 percent staff benefits. Construction material costs consist of $3,750 for 150 yards of delivered rock, $1,200 for logs, and $300 for rebar. Supply costs are $120-worth of tools and instruments, safety items, and clothing. Equipment costs include $1,000 for backhoe rental and $250 for tool rental. Other costs are $300 for transportation, $10 for fuel, $20 for photographic supplies, $10 for printing and duplicating, $680 for insurance, and $3,494 for administrative overhead.

The total cost of the earlier (1982 to 1983) McDonald Creek and Stone Lagoon restoration project is $30,846 (1984 dollars) (Table IV.7). Costs are fence construction, stock access installation, revegetation, planning, design, monitoring, and public education tools. Labor and material costs for installation of 8,000 feet of fencing equals $10,170, or $1.27 per foot. Labor, material and equipment costs of the installation of three stock access points with five flood gates equals $8,728, or $3,243 per unit. Costs for the planting of 7,400 trees equals $4,068, or $.55 per tree. Material costs for planting include 1,600 30-inch-diameter paper collars for a seedling survival test. These total direct costs do not include the costs of administration, planning and design, education, or monitoring, which are reported separately. The total cost of public education and awareness includes $200 for sign construction and $1,450 for the development of a watershed atlas. Planning and design costs consist of maps, plans, permits, subcontracts, materials, transportation, contract inspection, and review.

TABLE IV.7. Cost by Component, McDonald Creek and Stone Lagoon

| Project Component | Quantity | Unit | Equipment, Materials, Supplies, etc. | Labor | Total Costs ($1994) | Total Costs ($1984) |
|---|---|---|---|---|---|---|
| McDonald Creek/ Stone Lagoon, 1982-3 | | | | | | |
| Fence construction | 8,000 | ft | $2,860 | $7,310 | $14,359 | $10,170 |
| Stock access | 3 | LS | $6,064 | $3,664 | $13,735 | $9,728 |
| Revegetation | 7,400 | ea | $1,905 | $2,163 | $5,744 | $4,068 |
| Planning and design | | LS | $2,170 | | $3,064 | $2,170 |
| Monitoring | | LS | $780 | | $1,101 | $780 |
| Administration | | LS | $2,280 | | $3,219 | $2,280 |
| Education | | LS | $1,650 | — | $2,330 | $1,650 |
| **Total** | | | **$17,709** | **$13,137** | **$43,552** | **$30,846** |
| McDonald Creek, 1993 | | | | | | Costs ($1990) |
| Erosion control | 2 | LS | $9,681 | $37,708 | $53,190 | $47,389 |
| Instream structure installation | 6 | LS | $11,634 | $18,984 | $34,366 | $30,618 |
| **Total** | | | **$21,315** | **$56,692** | **$87,556** | **$78,007** |

Sources:

Bue, J. M, S.S. Madrone, and D. Allen. 1994. *McDonald Creek Restoration Project Final Report.* Prepared for California Department of Fish and Game by Redwood Community Action Agency, Eureka, California.

## Mill Creek Channel Improvements, Pennsylvania

Point of Contact:

Ronald Crull, Council President
Yoe Borough, Pennsylvania
150 North Maple Street
Yoe, PA 17313-1110
Phone: (717) 244-5904

Dennis Sarpen
James R. Holley & Associates
18 South George Street
York, PA 17401
Phone: (717) 846-4373

Project Description, Location, and Goals/Objectives:

The Yoe Borough Council contracted a project to design and construct gabion walls to control a severe streamside erosion problem and to provide a well-defined maintenance channel through the Borough. Gabion walls (steel cylinders filled with aggregate) were selected due to the higher cost of concrete walls. The gabion walls were constructed along a quarter-mile stretch on both sides of Mill Creek, a tributary to Codorus Creek and Susquehanna River. Mill Creek flows through the residential area of the Borough. Erosion of residential yards and commercial space by the creek was contributing a large sediment load to the watershed downstream. The project was conducted in three stages over a six-year period.

Engineering Features:

All three stages of the project were conducted from 1979 to 1987. Engineering features were as follows:

- 4.5-foot-high gabions
- 6-inch thick aggregate
- 6-foot-by-12-foot box culvert.

Other than the gabion walls, the only physical alteration to the site involved backfilling behind the walls. No maintenance has been conducted on the gabion walls to date; however, some scouring has been noted under the older sections of the walls.

## Monitoring Techniques:

None.

## Cost Analysis:

Costs are available for the third stage of the Mill Creek Channel Improvement project, which was completed in 1987. The total cost of the project was $52,600 (1987 dollars) (Table IV.8). A quarter-mile of stream was included in the action. Costs for the final stage included 512 linear feet of 4.5-foot-high gabions, installed at prices of $60 to $82.50 per linear foot, and 178 tons of aggregate, with costs ranging from $8.50 to $12 per ton. A large box culvert 16 feet long was also installed at a cost of $8,100. Some repair costs for earlier gabion walls is estimated at a cost of $6,000, but has not yet begun. No after-action monitoring was done.

TABLE IV.8. Cost by Component, Mill Creek Channel

| Project Component | Quantity | Unit | Equipment, Materials, Supplies, etc. | Labor | Total Costs ($1994) | Total Costs ($1987) |
|---|---|---|---|---|---|---|
| Engineering (for 1987 phase) | 1 | LS | $0 | $1,900 | $2,454 | $1,900 |
| 4.5-foot gabions | 192 | lf | $15,840 | | $20,455 | $15,840 |
| 6-inch thick aggregate | 28 | tons | $336 | | $434 | $336 |
| 4.5-foot-high gabions | 320 | lf | $19,200 | | $24,794 | $19,200 |
| 6-inch thick aggregate | 150 | tons | $1,275 | | $1,647 | $1,275 |
| 6-inch by 12-foot box culvert | 16 | ea | $8,100 | | $10,460 | $8,100 |
| Subtotal | | | $44,751 | $1,900 | $60,244 | $46,651 |
| Scouring repair[a] | 1 | LS | $6,000 | | $7,748 | $6,000 |
| **Total** | | | **$50,751** | | **$67,992** | **$52,651** |

(a) Some scouring repair is estimated for the older gabion walls at a cost of $6000; no maintenance requirements so far.

## Sources:

Chesapeake Bay Local Government Advisory Committee. 1991. *Chesapeake Bay Restoration: Innovations at the Local Level.* Pennsylvania. 74 pp.

## Stream Restoration Projects, California

Point of Contact:

Dr. G. Mathias Kondolf
University of California
College of Environmental Design
Berkeley, CA 94720-2000
Phone: (510) 644-8381

Project Description and Location:

Kondolf and Matthews (1993) examined the status of coarse sediment in rivers and streams in California for the purpose of evaluating management of this material. Although coarse sediment is relatively rare in streams and rivers, it is valuable for determining channel form in gravel-bedded rivers. In addition, it provides a major source of sediment to downstream portions of the river systems through breakdown and is of particular importance as spawning habitat for salmon and trout.

Project Goals/Objectives:

The objectives of their research were 1) to assess the magnitude and nature of the problem of managing coarse sediments in regulated rivers; 2) to assess the impacts on the physical system of dam construction and instream gravel mining by compiling basic data on hydrology, river channel, and aquatic habitat changes; 3) to inventory and evaluate strategies currently employed by dam operators, gravel extractors, and resource agencies; and, 4) to recommend comprehensive approaches for managing of coarse sediment to reduce environmental impacts and maintenance costs and to enhance presently degraded aquatic and riparian resources.

The report reviewed river processes, effects of reservoirs, reservoir management, effects of instream gravel mining, regulation, and management of instream gravel mining, recent restoration efforts and comprehensive environmental planning for coarse sediment management. This report represented a significant contribution to the understanding of restoration of gravel habitat in rivers.

Engineering Features:

Kondolf and Matthews (1993) found that recent restoration efforts have included the following:

- importation of gravel, scarification of immobile gravel beds
- construction of artificial side channels
- release of flushing flows
- construction of sediment traps
- mechanical excavation of pools filled with sediment
- restoration of channel geometry and riparian vegetation in disturbed streams.

They provided a table of 17 projects that lists each of these types of restoration efforts. The table identifies the overall cost to construct each project, which ranged from $800 to $19,800,000 (Appendix C).

Monitoring Techniques:

Kondolf and Micheli (1995) addressed the need for monitoring stream restoration projects, and identified and detailed the components of a postconstruction monitoring program. The components are as follows: fluvial geomorphology (i.e., channel capacity and floodplain inundation, channel stability, cross-section, streamflow, flood frequency, depth of water table and groundwater interactions, integration of geomorphic cross-sections, and ecology), water quality, biological habitat (aquatic organisms, wildlife, and bird populations), and photodocumentation.

Sources:

Kondolf, G.M., and W.V.G. Matthews. 1993. *Management of Coarse Sediment on Regulated Rivers.* Report No. 80. California Water Resources Center, University of California, Berkeley.

Kondolf, G.M., and E.R. Micheli. 1995. "Evaluating Stream Restoration Projects." *Environmental Management* 19:1-15.

## Tryon Creek Restoration Project, California

Point of Contact:

Mr. Steve Madrone
Redwood Community Action Agency
904 G Street
Eureka, CA 95501
Phone: (707) 445-0881

Project Description and Location:

Tryon Creek enters the Smith River two miles upstream from the river mouth and is located in Del Norte County, 10 miles north of Crescent City, California. A large volume of slash from early logging activity was left in the upper two miles of the stream. This slash trapped fine sediment, smothered spawning gravels, filled pools, and in some places could have been a barrier to fish passage. Almost all of the land surrounding the creek is in pasture, feed crops, or bulb fields. Much of the riparian vegetation has been cleared, and livestock has access to most of the stream.

Project Goals/Objectives:

The general objectives of this project were to improve and restore instream fish rearing and spawning habitat and riparian wildlife habitat, and to increase open-water habitat for birds. The specific objectives of each of the lower reach project components were as follows: 1) to create one long, continual summer pool that would provide adequate shelter and temperature for increased aquatic life, to be accomplished by dredging areas of silt accumulations that were deposited from the 1955 and 1964 floods; 2) to protect the sensitive riparian area, to be accomplished by fencing the riparian area and excluding the livestock; and 3) to restore the riparian vegetation, to be accomplished by planting appropriate species in the stream and slough riparian areas. The specific objective of the upper reach project component was to eliminate barriers to fish migration and to facilitate the flushing of fines from impacted and buried spawning gravels.

Engineering Features:

Dredging, fencing, and planting took place between 1984 and 1988. The dredging work took much more time to complete than originally estimated due to the volume of woody debris buried in the silt. A total volume of over 10,000 cubic yards was dredged from the main channel of Tryon Creek and a tributary slough, using a drag-line excavator. Dredged materials were spread out by a crawler tractor, front-end loader, and dump truck. Most of the materials were spread on adjacent agricultural lands, but those with a high gravel content were spread on farm roads. Two culverts

were installed at the site of an old low-water, summer crossing to allow winter access for cattle to various pastures on the north and south sides of the creek.

A total of 13,500 feet of fencing was constructed 20 to 70 feet back from the mean high water level of the creek. Five strands of barbed wire were strung along wooden and metal posts. The lowest wire was 12 inches off the ground to keep calves out of the fenced area.

A total of 13,805 deciduous and coniferous bare-root trees, and 3,000 cuttings were planted throughout the fenced riparian areas. Red alder, red maple, English maple, European birch, red oak, green ash, mountain ash, and Norway maple were planted close to the creek at 3- to 8-foot spacing. Douglas fir, spruce, incense cedar, bishop pine, grand fir, ponderosa pine, and Scotch pine were planted on the upper banks at 3- to 8-foot spacing. Planting was performed during the summer period of low streamflow to minimize sedimentation.

Monitoring Techniques:

Project documentation included twice-monthly surveys of bird species for a one-year period following construction; before, during, and after construction photographs; in addition to ongoing general observations by the landowner. In 1986, additional monitoring included a water quality survey, vertebrate and invertebrate sampling, an avian survey, and a riparian vegetation stocking survey. Dissolved oxygen, pH, and temperature levels were all within the ideal range for suitable fish habitat. $CO_2$ levels were slightly elevated (range from 10 to 15 parts per million). No fish were captured; this was attributed to improper sampling gear. The most abundant invertebrates captured were caddis fly larvae and fresh water snails, both of which are known to be important food items for fish. One hundred and nineteen species of birds were observed at the site, including one bald eagle and one peregrine falcon. The mixed conifer and hardwood seedlings showed good survival upstream of the road crossing. Downstream of the road crossing, almost 30 percent of the seedlings had been damaged by beaver browsing.

Cost Analysis:

The total cost of the Tryon Creek stream enhancement project is $80,984 (1988 dollars) (Table IV.9). The total reimbursable costs for the project equal $45,834; total contributions equal $35,150. Costs represent subcontracts, labor, materials, equipment, travel, and administration for dredging of areas of silt accumulation, fencing of riparian areas, and revegetation of stream and slough riparian areas. The cost of dredging 10,000 cubic yards of material (including the installation of two culverts to allow for winter access by cattle) is reported as $42,442 (including $21,850 in donated equipment time and labor) or $4.24 per cubic yard. Equipment consists of a drag-line excavator, crawler tractor, front-end loader, and a dump truck. A total of 13,500 feet of fencing was constructed by the landowner 20 feet to 70 feet back from the mean high water level of the creek. Costs of fencing are $20,250 for materials and labor ($0.81 per foot for materials and $0.69 per foot for labor) and $1,758 in donated labor and materials. The cost of planting 13,805 trees and 3,000

pole cuttings is $4,992 for tree planting and mulch spreading, $10,000 in labor donated by the California Conservation Corps, and $1,430 in labor and trees donated by the landowner. In addition to the basic components of the project, an archaeological survey costing $112 was contributed.

TABLE IV.9. Cost by Component, Tryon Creek

| Project Component | Quantity | Unit | Equipment, Materials, Supplies, etc. | Labor | Total Costs ($1994) | Total Costs ($1988) |
|---|---|---|---|---|---|---|
| Dredging (culvert installation included) | 10,000 | cy | $42,442 | | $52,631 | $42,442 |
| Fencing | 13,500 | lf | $12,693 | $9,315 | $27,291 | $22,008 |
| Revegetation (trees and plant cuttings) | 16,805 | ea | $16,422 | | $20,364 | $16,422 |
| Archaeological survey | | LS | $112 | | $139 | $112 |
| **Total** | | | **$71,669** | **$9,315** | **$100,425** | **$80,984** |

Sources:

Madrone, S.S. 1988. *Tryon Creek Instream and Riparian Enhancement and Restoration.* Final Report Prepared for California State Coastal Conservancy by Redwood Community Action Agency, Eureka, California.

## Upper Little Swatara Creek Adopt-A-Stream Project, Pennsylvania

Point of Contact:

Mr. Craig Morgan, District Manager
Schuylkill County Conservation District
7197 Fairlane Village Mall
Pottsville, PA 17901
Phone: (717) 429-1744

Project Description, Location, and Goals/Objectives:

The Schuylkill County Conservation District "adopted" a one-mile stretch of the Little Swatara Creek as part of the State of Pennsylvania's Adopt-A-Stream Program. The goals of this multiyear project were to alleviate stream bank erosion and to restore stream physical features (Chesapeake Bay Local Government Advisory Committee 1991). Ecological objectives included the elimination of bare soil areas, the reduction of stream width during low flow periods, and restoration of native species (willow). The project was implemented in three phases:

- Year 1--installation of over 1.5 miles of electric fencing to restrict access of cattle to the streambanks, allowing revegetation

- Year 2--installation of 400 tons of stone riprap and 210 railroad ties to act as stream deflectors and to create a mud sill along the stream banks, and two cattle crossings to control access

- Year 3--planting of 300 willow tree saplings to stabilize the streambanks.

The restored areas are currently open to the public for recreational uses, and the site will be highlighted as a demonstration for others interested in developing similar adopt-a-stream projects.

Engineering Features:

The construction phase of the project was begun in 1987 and completed in 1988. Engineering features included the following:

- two log frame deflectors

- two stone deflectors

- cattle crossing
- 180 feet of mud sills
- riprap banks
- fencing (donated).

No physical alterations to the site were necessary; no maintenance of the site is planned.

Monitoring Techniques:

Annual visual inspections of the site are conducted by the Pennsylvania Fish Commission. Results to date indicate good revegetation of the streambanks by willow and canarygrass, and a good blending of new physical structures with the natural surroundings.

Cost Analysis:

The total cost of the Upper Little Swatara Creek restoration project is $13,000 (1987 dollars) (Table IV.10). Funding assistance for the project from the Agricultural Stabilization and Conservation Service and the State Conservation Commission is reported as $15,000. Costs include the direct cost of the installation of two log frame deflectors (with donated poles) at $900 each, two stone deflectors at $200 each, one cattle crossing at $800, two mud sills (180 feet) at $4,000 each, and riprap bank (including 400 tons of material) for $2,000. The installation of 1.5 miles of cattle fence is reported as donated. Engineering and design are reported as "in-kind." Lump sum costs for each component of the project account for materials and labor. Labor costs were estimated to be one-half the total cost of each component.

TABLE IV.10. Cost by Component, Upper Little Swatara Creek Adopt-A-Stream

| Project Component | Quantity | Unit | Equipment, Materials, Supplies, etc. | Labor | Total Costs ($1994) | Total Costs ($1987) |
|---|---|---|---|---|---|---|
| Log frame deflectors | 2 | each | $900 | $900 | $2,324 | $1,800 |
| Stone deflectors | 2 | each | $200 | $200 | $517 | $400 |
| Cattle crossing | 1 | LS | $400 | $400 | $1,033 | $800 |
| Mud sills | 360 | lf | $4,000 | $4,000 | $10,331 | $8,000 |
| Riprap banks | 400 | tons | $1,000 | $1,000 | $2,583 | $2,000 |
| **Total** | | | $6,500 | $6,500 | $16,788 | **$13,000** |

Sources:

Chesapeake Bay Local Government Advisory Committee. 1991. *Chesapeake Bay Restoration: Innovations at the Local Level.* Pennsylvania. 74 pp.

## Water Quality Monitoring and Assessment of Agricultural Best Management Practices (BMPs), Florida

Point of Contact:

Dean M. Campbell
St. Johns River Water Management District
P.O. Box 1429
Palatka, FL 32078-1429
Phone: (904) 329-4360

Project Description and Location:

The purpose of this project was to identify, install, or initiate agricultural best management practices (BMPs) and to evaluate their effectiveness in reducing nutrient and sediment loadings to receiving waters within the St. Johns River Water Management District (SJRWMD), Florida.

A host of Natural Resources Conservation Service (NRCS)-approved BMPs, including nutrient management, water management, and sediment control measures, non-SCS-approved water management measures, and regional treatment alternatives were evaluated. The most economically viable methods are currently being tested in the field. Computer modeling is being employed to evaluate measures not applied in the field. Modeling was also used as a means of preevaluating methods.

Project Goals/Objectives:

This project was developed to identify viable BMPs that are effective in reducing pollution (nutrient and sediment) loads to receiving waters, to evaluate their effectiveness, and to make recommendations for area-wide application and adoption. The ecological performance criteria for the BMPs were reduced nutrients in discharge water, reduced loading, increased biodiversity in benthic organisms in receiving waters, and improved water quality in receiving streams.

Engineering Features:

Nonstructural BMPs are being evaluated first. No extensive construction is currently proposed, although regional treatment facilities could entail massive construction. Individual site alterations were limited to sediment trap construction with major discharge ditches. Maintenance is limited to monitoring equipment and applications associated with nutrient management practices on each field. Originally, 10 farms in three counties were evaluated, some more intensively than others. Currently, the study involves four project farms in three counties.

Monitoring Techniques:

Standard water quality monitoring techniques for ground and surface water are being used, as well as tissue analysis of crops, atmospheric deposition, yield assessment, and grab and automated sampling. Monitoring is conducted weekly during the growing season (January-May) and biweekly during the fallow season. Performance is directly related to meteorological conditions (i.e., wet year or dry year) and modeling helps to fill data gaps and adjust results according to weather conditions.

Cost Analysis:

The total cost of the SJRWMD project was $932,782 (1994 dollars) (Table IV.11). This total includes EPA Clean Water Act Section 319 funds and a SJRWD match. The project is expected to continue through 1995. Costs are labor for two years, actual BMP implementation, equipment (computers), and subcontracts. Subcontracts have been let to SCS ($100,000); University of Florida Institute for Food and Agricultural Service for economic analysis ($6,435), education brochure ($2,500), soil and tissue samples ($1,165), 5 percent overhead ($1,165), and travel ($4,400); pesticide sampling analysis ($23,500); a biomonitoring study ($15,000); a water sampling program ($379,000); pesticide sampling program ($15,782); water quality analysis ($150,000); and biological sampling ($40,000). Labor costs are for a field technician ($54,000), a technical program manager ($17,000), an environmental specialist ($44,000), and an engineer ($24,000). The BMP implementation component of the project includes demonstrations on four farms. The costs cover nominal land rental, contracts, labor, equipment, and documentation. Labor costs are minimal, because the majority of work in implementation of BMPs is performed by the growers. The contract price for land lease is $125/acre for Year 1 and $200/acre for Year 2. Costs of labor are included in the land lease price. An additional $490,000 has been proposed to conduct work in 1995.

TABLE IV.11. Cost by Component, St. Johns River Water Management District

| Project Component | Quantity | Unit | Equipment, Materials, Supplies, etc. | Labor | Total Costs ($1994) |
|---|---|---|---|---|---|
| BMP Planning | | LS | $164,000 | $54,000 | $218,000 |
| BMP Implementation | | LS | $90,000 | | $90,000 |
| Subtotal: Phase I EPA Funding | | | | | $308,000 |
| BMP Planning and Implementation | | LS | $544,782 | $80,000 | $624,782 |
| Subtotal: Phase 1 SJRWD Match | | | | | $624,782 |
| **Total** | | | **$798,782** | **$134,000** | **$932,782** |

Sources:

Project files and personal communication with Dean Campbell.

## Clinton County Solid Waste Authority Mitigation Wetland, Pennsylvania

Point of Contact:

Mr. John W. Munro
Munro Ecological Services, Inc.
990 Old Sumney Town Pike
Harleysville, PA 19437
Phone: (610) 287-0671

Project Description and Location:

The Wayne Township Landfill site is located in Wayne Township, Clinton County, Pennsylvania. The 256.14-acre site includes an existing landfill facility, as well as shrub and mixed deciduous forest lands modified by previous logging, clearing, and pasturing (Munro 1992). Munro Ecological Services, Inc. (MES) has designed mitigation habitats totalling 13.18 acres, of which 5.19 acres will be new constructed wetlands (Munro 1993a). These mitigation wetlands and their associated upland habitats will be situated within a 40+-acre preserve to be protected in perpetuity from further intrusive development by a binding conservation easement. Existing undisturbed palustrine wetlands totalling 7.17 acres will also be protected within the preserve's boundaries. The existing mosaic of undisturbed wetlands and upland forest was used as a template for the constructed wetlands.

Project Goals/Objectives:

The overall goal of this project is to provide onsite, in-kind mitigation for the proposed and permitted loss of 13 jurisdictional wetlands (2.33 acres) resulting from a 24-acre expansion of the Wayne Township Landfill. Following are the stated mitigation goals (and management measures) for the project (Munro and Stiles 1993a):

- to provide permanent replacement for 2.33 acres of wetlands affected by landfill construction
- to maintain continuity with the existing mosaic pattern of small wetlands surrounded by upland forest that is characteristic of the site but is of uncertain origin
- to move Lake Wayne, its wetland material, and microsetting to a new location about 1,000 feet from its present location in as thorough a manner as is practicable
- to construct wetland systems in which ecosystem structure and functions will develop similarly to the naturally occurring local wetland mosaic system

- to use all surface water and near-surface groundwater available for the mitigation area on the site in hydrologic systems designed to represent natural wetland systems
- to increase the extent of wetland on the site and to locate the constructed wetlands in relation to existing wetlands in such a way as to enhance their wetland values
- to salvage wetland and upland stock from the impact areas for use in the mitigation wetlands
- to carefully and selectively transplant some onsite and offsite local wetland shrubs, herbs, and forbs to augment the smaller sized purchased stock and to provide some plant stock that is genetically adapted to local conditions
- to select and plant vegetation in such a way as to create a natural and attractive appearance
- to plant native vegetation in the most suitable soil moisture regimes with sufficient species diversity to provide a variety of food and habitat resources for wildlife
- to provide a vegetated upland visual buffer between the mitigation areas and the landfill facility
- to use diverse planting methods that will provide at least 85 percent live cover within two growing seasons
- to avoid the need for long-term maintenance by using low maintenance design strategies for the permanent wetland areas
- to provide sufficient wildlife amenities to encourage residence and breeding by various wildlife species that will find suitable onsite habitat
- to establish and implement a 5-year monitoring plan to insure the highest level of project success possible and to provide a scientific basis for studying the constructed wetland systems.

Engineering Features:

The first phase of the required mitigation was completed in summer 1994. The second phase is to be constructed in 1995. Each phase entails approximately 50 percent of the work. No "hard" engineering was needed in Phase 1. Compacted clay liner areas (12 to 24 inches thick), six wetland basins with interior surface elevations of 0 to 1 foot above the typical wet-season water level, and outlet headwalls were constructed. Soils used in regrading and surfacing the area were from the site. Other physical alterations to the site involved clearing of woodland and scrub areas, regrading of

contours, and rebuilding of shallow water table (clay lined areas). Hidden and buried wet peat deposits estimated to be 10,000 to 12,000 years old had to be removed and filled with solid substrate. A "native thick-sod system," designed by MES, was used to successfully move intact 0.5 acres of buttonbush marsh to a new replicated location 1,000 feet from its original location. The system consists of a cutting implement that can be mounted on a loader, transport pallets designed to be carried on standard flatbed trailers, a sod-hoe to pull the sod from the transport pallet into its placement location, a placing implement to press the sod firmly into place, and a fork lift to move the transport pallets. Planting of wetland vegetation was modeled on the most multifunctional wetlands of the site. Wetland communities that were planted are herbaceous marsh, bog, shrub swamp, and swamp forest. Upland buffer areas around the constructed wetlands will contain mixtures of grasses and wildflowers, upland shrub, and upland mixed forest. Both propagated and salvaged planting stock will be used. Water level control structures will be constructed in several wetland basins. The remaining basins will have fluctuating water levels, thus emulating the existing wetland areas.

The following outline provides a summary of Phase 1 and Phase 2 construction (Munro and Stiles 1993a):

<u>Phase 1 (1993-1994)</u>

- setup of survey control points at basin construction sites
- earthwork and placement of liner and topsoil on the wetland cells that include the new Lake Wayne, as well as Basins 5 through 7 and 9 through 11
- moving of Lake Wayne sod and plant stock to new location
- planting of purchased stock
- seeding of wetlands and uplands
- placement of wildlife structures
- as-built survey of constructed wetlands
- placement of wetland reference marks, boundary stones, and shallow monitoring wells.

<u>Phase 2 (1995-1996)</u>

- earthwork and placement of liner and topsoil on wetland cells in Basins 1 through 4 and 12 through 13

- planting of salvaged trees and shrubs
- planting of purchased stock
- placement of wildlife structures
- as-built survey of constructed wetlands
- placement of wetland reference marks, boundary stones, and shallow monitoring wells.

MES contends that similar values and levels of complexity will develop in the constructed wetlands relative to the natural wetland communities on the site, because of the comparable hydrologic systems, transfer of wetland soils, transplanting of wetland vegetation, use of seed and plant stock collected from local wetlands, use of native plant species, and a diversity of wildlife habitat. In addition, no-maintenance structural designs should help to ensure the long-term success of this project.

Monitoring Techniques:

As a permit condition for this project, wetland structure and function, as well as the success and survival of planted vegetation, will be monitored monthly through the growing season for a five-year period. The monitoring procedures are designed to provide documentation of the required 85 percent cover (herbaceous wetland areas) and of survival (woody plants) of the planted stock, as well as other biological and physical parameters; these parameters are surface and groundwater levels, surface and groundwater quality, colonization by animal populations adapted to wetland settings, and presence of wetland soils. The monitoring techniques are also designed to provide a visual documentation of conditions, in addition to annotated and summarized data. Thirteen shallow monitoring wells will be installed, one in each basin, to allow monitoring of the depth of the constructed wetlands' perched water table.

Results of Year 1 (1994) monitoring are not yet available. Preliminary indications are that the wetlands were constructed according to the plan and that they are already well used by wildlife. Five years of monitoring will determine whether or not the system performs well relative to the performance goals and criteria.

Cost Analysis:

The total cost of the Clinton County Solid Waste Authority Mitigation Wetland project is estimated by the contractor to be $624,000 (1994 dollars). These costs include labor and materials for survey work at $37,000; earth work at $244,000; planting, landscaping, and moving 0.5 acre of intact buttonbrush marsh at $182,000; permits, alternatives analysis, and related activities at $100,000; and construction supervision and oversight at $15,000 (Table IV.12). The project was

designed for minimum maintenance; however, yearly maintenance will be required for the 20-plus nest boxes and elimination or control of exotic and invasive plants (cost not given), and for monthly monitoring for a period of five years (annual cost estimated at $21,000 to $25,000).

TABLE IV.12. Cost by Component, Clinton County, Pennsylvania, Landfill Expansion

| Project Component | Quantity | Unit | Equipment, Materials, Supplies, etc. | Labor | Total Costs ($1994) |
|---|---|---|---|---|---|
| Compacted clay liners | 3 | LS | | | |
| Wetland basins | 6 | LS | | | |
| Outlet headwalls | 3 | LS | | | |
| Surveying | 1 | LS | | | $37,000 |
| transporting 0.5 acre of wetland | 0.5 | acre | | | $182,000 |
| Earth works | 1 | LS | | | $244,000 |
| Oversight and construction supervision | 1 | LS | | | $15,000 |
| Mitigation plan | 1 | LS | | | $30,000 |
| Construction details document | 1 | LS | | | $6,000 |
| Bidding documents | 1 | LS | | | $10,000 |
| alternatives analysis processing | 1 | LS | | | $100,000 |
| **Total** | | | | | **$624,000** |

Sources:

Munro, J.W. 1992. *Wetland Inventory and Evaluations for the Wayne Township Landfill Site, Clinton County Solid Waste Authority.* Munro Ecological Services, Inc., Harleysville, Pennsylvania.

Munro, J.W., and S. A. Stiles. 1993a. *Wetland Construction Plan for the Mitigation Area on the Wayne Township Landfill Site, Clinton County Solid Waste Authority in Wayne Township, Clinton County, Pennsylvania.* Munro Ecological Services, Inc., Harleysville, Pennsylvania.

Munro, J.W., and S. A. Stiles. 1993b. *Monitoring Plan for the Clinton County Solid Waste Authority Wayne Township Landfill Mitigation Sites.* Munro Ecological Services, Inc., Harleysville, Pennsylvania.

## Hard Rock Mine Constructed Wetland, Alabama

Point of Contact:

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Project Description and Location:

The Tennessee Valley Authority (TVA) has designed and constructed a wetlands system to treat acid mine drainage at TVA Hard Rock Coal Mines, Jackson County, Alabama. Acid drainage occurs under natural conditions when certain coal seams are mined and the associated acid-forming overburden is exposed to an oxidizing environment. TVA's first constructed wetland for acid drainage treatment was located at the Fabius, Alabama, coal mines and coal preparation plant in Jackson County, Alabama. The success of the Impoundment 1 Wetland (Brodie et al. 1987a) at treating pH, iron, manganese, and suspended solids to meet permit effluent limitations led to an extensive research and demonstration project and the construction of other treatment wetlands at numerous TVA facilities.

Project Goals/Objectives:

The goals of the Hard Rock Mine project were to reduce iron (Fe), manganese (Mn), and total suspended solids (TSS) concentrations in acid mine drainage to compliance levels in a cost-effective, environmentally sound manner. Chemical treatment, land reclamation, and alkaline groundwater recharge were evaluated as alternatives to the constructed wetlands system. The constructed wetland was chosen for the following reasons: 1) it had the lowest total cost, 2) it extended a TVA research and development program, 3) it had the highest probability of long-term viability, and 4) it incurred the lowest annual operation and maintenance (O&M) costs. The system was expected to provide diverse habitat for wildlife in the constructed wetland, including deep and shallow water, riparian, and upland, and also to improve receiving stream water quality so that it could support diverse macroinvertebrate and vertebrate species, including indigenous fish. In addition to TVA, other agencies involved in this project were Alabama Department of Environmental Management (National Pollutant Discharge Elimination System [NPDES] permit), Alabama Surface Mining Commission (mining and reclamation permit coordination), and U.S. Army Corps of Engineers (approval of impacts to existing wetlands). The project was funded by the TVA Office of Power.

Engineering Features:

The constructed wetland was built between 1991 and 1992, with modifications in 1993 and 1994. The following physical structures were built:

- one anoxic drain, Hard Rock North (HRN), 1991
- one oxidation pond, HRN, 1991
- Cell* 1, 1991
- Cell 2, 1991
- Cell 3, 1991
- one diversion dam and conveyance, 1991
- Cell 4, 1992
- one anoxic drain, Hard Rock South (HRS), 1992
- one oxidation pond, HRS, 1992
- Cell 5, 1992
- two cell liners (Cells 1 and 2), 1993
- one Cell 4 emergency spillway, 1993
- modifications, 1994.

* a cell is a pond, or a partitioned subsection of a pond.

Proper hydrologic sizing of the wetland cells and spillways is the most critical aspect of wetlands design, because inadequacies could result in channelization, stagnation, system flushing, spillway failure, and biotic mortality, any of which could severely impact the wetlands capacity for treatment and self-maintenance (Brodie et al. 1987b).

Monitoring Techniques:

Wastewater characterization and site hydrology are the two most important predesign data needs for constructed wetlands. Maintenance of a proper hydrologic balance and influent water

quality can greatly influence the system hydraulics and the viability of the aquatic biota that are essential to wetlands treatment (Brodie et al. 1987b). Preconstruction, baseline monitoring at Hard Rock Mine addressed groundwater, soil, water chemistry, and macrobenthos using EPA standard methods. Post-construction monitoring entailed all of the above twice each month, as well as quarterly in-wetlands water quality and flow monitoring, and anoxic limestone drain performance data. These methods were excellent in assessing the performance of the system. The system exceed the NPDES compliance requirements: average iron removal was greater than 98 percent (range 50 milligrams/liter to <1.0 milligrams/liter [.007 ounces/gallon to <.0001 ounces/gallon]); average manganese removal was greater than 95 percent (range 17 milligrams/liter to <1.5 milligrams/liter [.002 ounces/gallon to <.0002 ounces/gallon]). Relative to conventional techniques (e.g., chemical treatment, land reclamation, alkaline groundwater recharge), constructed wetlands offer an inexpensive, self-maintaining, long-term solution to treating acid drainage of moderate flows and chemical concentrations.

The current study phase of the project is NPDES compliance. Monitoring is focused on in-wetland water quality, biological (macroinvertebrate and vertebrate), and anoxic limestone drain monitoring.

Cost Analysis:

The wetland constructed for mitigation of acid mine drainage at TVA's Hard Rock coal mine in Jackson County, Alabama, was constructed at a cost of about $615,000 (1991 dollars) (Table IV.13). Equipment time represented $380,000 (62 percent); labor represented $120,000 (19 percent); materials and miscellaneous represented about $90,000 (15 percent); and site supervision represented about $25,000 (4 percent). Major identified structures accounted for $581,000 of the costs. Engineering and design cost about $35,000, which brought the total to about $650,000. A mix of twice-monthly and quarterly monitoring cost $7,000 in 1993 and $5,000 in 1994; it is expected to cost about $3,000 per year in the future.

Cost breakdown by object consists of equipment at $380,000, labor at $120,000, site supervision at $25,000, materials and miscellaneous at $90,000, and engineering at $35,000. Additional monitoring costs were $7,000 in 1993 and $5,000 in 1994.

TABLE IV.13. Cost by Component, Hard Rock Mine

| Project Component | Quantity | Unit | Equipment, Materials, Supplies, etc. | Labor | Total Costs ($1994) | Total Costs ($1991) |
|---|---|---|---|---|---|---|
| HRN Anoxic Drain | 1 | LS | | | $66,780 | $62,000 |
| HRN Oxidation Pond | 1 | LS | | | $21,542 | $20,000 |
| Cell 1 | 1 | LS | | | $59,240 | $55,000 |
| Cell 2 | 1 | LS | | | $48,469 | $45,000 |
| Cell 3 | 1 | LS | | | $96,938 | $90,000 |
| Diversion Dam And Conveyance | 1 | LS | | | $23,696 | $22,000 |
| Cell 4 | 1 | LS | | | $59,240 | $55,000 |
| HRS Anoxic Drain | 1 | LS | | | $37,698 | $35,000 |
| HRS Oxidation Pond | 1 | LS | | | $46,315 | $43,000 |
| Cell 5 | 1 | LS | | | $80,782 | $75,000 |
| Cell 4 Emergency Spillway[a] | 1 | LS | | | $43,084 | $40,000 |
| Cell 1 & 2 Liners | 1 | LS | | | $18,311 | $17,000 |
| Modifications | 1 | LS | | | $23,696 | $22,000 |
| Other | 1 | LS | | | $14,002 | $13,000 |
| Repairs | 1 | LS | | | $22,619 | $21,000 |
| Subtotal | | | | | $662,412 | $615,000 |
| Engineering | 1 | LS | | | $37,698 | $35,000 |
| **TOTAL** | | | | | **$701,110** | **$650,000** |

(a) $40,000 includes about $20,000 in specific repair costs.

Sources:

Brodie, G.A., D.A. Hammer, and D.A. Tomljanovich. 1987a. "Treatment of Acid Drainage from Coal Facilities with Manmade Wetlands." In *Aquatic Plants for Water Treatment and Resource Recovery*, K.R. Reddy and W.H. Smith, eds., pp. 903-912. Magnolia Publications, Inc., Orlando, Florida.

Brodie, G.A., D.A. Hammer, and D.A. Tomljanovich. 1987b. "Constructed Wetlands for Acid Drainage Control in the Tennessee Valley." In *Increasing Our Wetlands Resources,* J. Zelazny and J.S. Feierabend, eds., pp. 173-180. Proceedings of a National Wildlife Federation Conference, Washington, D.C.

## Highway 237 Wetland Mitigation Site, California

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Project Description and Location:

The Highway 237 wetland was constructed to compensate for impacts caused by widening of Highway 237. The impacts included loss of 17.4 acres of seasonal wetlands and 1.2 acres of brackish marsh between Mountain View and Milpitas in Santa Clara County, California. The site is located along the northern side of the Highway next to San Tomas Aquino Creek and Calabasas Creek. The mitigation site covers a total of 50 acres, and is surrounded by levees.

Project Goals/Objectives:

The goal for the project was to create new seasonal wetlands by creating seasonal ponding. To accomplish this, small isolated wetlands were consolidated into one large unit, and were made contiguous to existing wetlands. These existing wetlands were also enhanced. As constructed, the system contained more than 22.5 acres of new wetlands and associated habitats created by excavating upland portions of the site. Performance criteria established for the project stated that the vegetated habitats (brackish marsh, vegetated seasonal wetland and upper marsh/transition) would be 80 percent cover after five years, as determined by line intercept sampling.

Engineering Features:

The design included creation of three large, shallow ponds with six water control structures within the 50-acre site. Pond 1 received flow from two creeks through concrete box culverts. Outflow to Pond 2 is through a weir structure in a low levee or through a 1-foot-diameter corrugated metal pipe culvert with slide gate. Flow to Pond 3 is through a vegetated swale in another low levee. There is a second 1-foot-diameter pipe culvert between Ponds 2 and 3 with a slide gate. The latter structure facilitates lower water surface elevations or complete drainage of the ponds. Pond 3 flows into an adjacent slough through a 4-foot-diameter pipe culvert with an outside slide/flap gate.

The major engineering activities and features included the following:

- excavation of overburden in the areas of Ponds 1 and 2
- construction of low berms separating Ponds 1 and 2, and Ponds 2 and 3
- installation of weirs with flashboards on two creeks flowing into Pond 1
- installation of a flashboard weir and 12-inch culvert with slide gate between Ponds 1 and 2
- installation of a 12-inch culvert with slide gate between Ponds 2 and 3
- installation of a 48-inch culvert with combination slide/flap gate at the outlet of Pond 3.

Monitoring Techniques:

Monitoring included hydrology, sedimentation, vegetation, soils, and wildlife. Tidal hydrology was measured using recording tide gauges at two locations within the pond system and one outside the site in a slough that received outflow from the site. Annual rates of deposition in the ponds were measured with a variety of sediment traps and surveyed elevation stations. Dominant plant associations were mapped by walking the perimeter of the site and recording the plant associations on a map. The cover of vegetation within each association was quantified using one-square-meter (1.196-square-yard) quadrats placed along transects. Soil cores were taken at five locations and were analyzed for soil moisture, pH, and salinity. Birds were monitored during eight visits within each of the four seasons. Data were gathered on the number of individuals of each species, location, and behavior (e.g., feeding, resting, and movement). Wind speed, amount of standing water, and ambient temperature were also recorded. The monitoring results in 1993 showed that the system was occupied by a large number of bird species and that vegetation was developing as predicted. Hydrology was also generally as predicted.

Cost Analysis:

This project cost approximately $800,000 in 1992 dollars ($836,493 in 1994 dollars) to restore 20 acres of wetlands and create an additional 20 acres of new wetlands. This is the construction cost only. No land acquisition costs were mentioned as part of the total. Labor and materials costs were not separately available. The engineering plans and specifications cost approximately $100,000 to produce (not included in the $800,000 required to construct the project). No information is available on the costs of the monitoring program.

Sources:

Coats, R., and H.T. Harvey. 1989. *Wetland Mitigation Plan for Widening of Highway 237.* Philip Williams & Associates, San Francisco, California.

H.T. Harvey and Associates, Philip Williams & Associates, and San Jose State University. 1993. *Highway 237 Wetland Mitigation Site Annual Monitoring Report.* Prepared for Caltrans and San Jose State University Foundation. H.T. Harvey & Associates, Alviso, California.

## Municipal Wastewater Treatment By Constructed Wetlands, Kentucky

Point of Contact:

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Project Description, Location, and Goals/Objectives:

TVA was one of the first institutions to promote the feasibility and benefits of using constructed wetlands for treating domestic sewage. TVA constructed three different types of full-scale demonstration treatment systems in the western Kentucky cities of Benton (1986), Hardin (1987), and Pembroke (1987) to do the following: 1) evaluate the relative advantages and disadvantages of these three types of constructed wetlands; 2) determine ability to comply with permit parameters; 3) evaluate basic design and operation factors and develop criteria; 4) evaluate cost-effectiveness; and 5) promote technology transfer to users and regulators (Steiner et al. 1987). These systems subsequently replaced or significantly upgraded each town's municipal wastewater treatment facility. All three systems were designed to meet advanced level effluent limits for biological oxygen demand (BOD), TSS, and ammonia-nitrogen. The Benton "gravel marsh and surface flow marsh" system serves a population of 4,200 and treats primary effluent in a lagoon. The Hardin "soil bed marsh" system serves a community of 545 and treats comminuted, aerated influent. The Pembroke "marsh-pond-meadow" system serves 1,100 people and treats comminuted, aerated influent.

Engineering Features:

The Benton treatment system originally consisted of a two-cell, 26-acre lagoon. The system was modified by changing the 10-acre second cell of the lagoon into a three-cell constructed wetland for inexpensive "polishing" of lagoon effluent. Cell 1 consists of native clay soil and was planted with mostly cattails, along with a few decorative plant species. Cell 2 contains native clay substrate and was planted with woolgrass and softstem bulrush. Cell 3 contains an average of 2 feet of gravel-sized, crushed limestone and was planted with softstem bulrush. Cells 1 and 2 were designed to operate as surface flow systems and for each to receive 25 percent of the total flow, whereas Cell 3 was designed to operate as a subsurface flow system with each to receive 50 percent of the total flow. The wetland system was sized for an average flow of 1.1 million gallons/day (mgd) and receives effluent from the remaining 16-acre lagoon.

The Hardin system was built to polish effluent from the existing package contact stabilization plant. The wetland system consists of native soil and limestone, engineered to have a specific hydraulic conductivity range to promote subsurface flow. The system was designed for 100,00 gallons/day (gpd) and has two equally-sized marsh cells that receive equal flow. Cell 1 was planted with common reed, whereas Cell 2 was planted with softstem bulrush. A diked hardwood area has a storage capacity of 1.5 million gallons, and is used to manage excessive inflow/infiltration entering the collection system during storm events.

The Pembroke system consists of two parallel and independent marsh-pond meadow systems, each having in series two parallel marsh cells, a pond, and a meadow. System A contains crushed limestone gravel and was designed to create subsurface flow. System B consists of native loamy clay soils and was designed to promote primarily surface flow. Only System B was planted. Cattails and softstem bulrush were planted in the surface flow marsh, duckweed was seeded in the pond, and reed canarygrass was sown in the meadow.

A summary of project engineering features for municipal wastewater treatment is as follows:

| Feature | Benton | Hardin | Pembroke |
|---|---|---|---|
| Type of Wetland | Gravel marsh and surface flow marsh | Soil bed marsh | Marsh-pond-meadow |
| Design flow | 1.1 mgd | 100,000 gpd | 89,000 gpd |
| Pretreatment | sedimentation; biochemical oxidation | comminution; aeration | comminution; aeration |
| Application rate | 64 acres/ft$^3$/s (92 ha/m$^3$/s) | 9.5 acres/ft$^3$/s (135 ha/m$^3$/s) | 26.5 acres/ft$^3$/s (379 ha/m$^3$/s) |
| Total surface area | 10.9 acres (3 equal cells) | 1.5 acres (2 equal cells) | 1.7 acres (4 equal cells) |
| Length/width ratio | 7.6:1 each cell | 0.33:1 each cell | 8.2:1 each cell |
| Slope liner | 0.1% | 4.0% | 0.1% |
| Vegetation | bulrush + others | reed, bulrush | cattail, bulrush canarygrass, duckweed |
| Substrate | gravel, native soil | native soil w/ limestone | native soil w/ limestone |
| Post-treatment | chlorination | chlorination; aeration | chlorination; aeration |

Monitoring Techniques:

Knight (1991) summarized the survival and condition of planted vegetation at the three constructed wetland treatment systems. There was no obvious causal factor that explained the variety of plant survival and health conditions observed in different cells of the constructed wetlands. Based on a review of the literature, Knight developed a number of hypotheses to explain the variable plant growth. Choate et al. (1989, 1990, 1993) and Watson et al. (1990), summarized monitoring data for the March 1988 to August 1991 period. All three constructed wetland systems reduced BOD, TSS, and fecal coliform, but none of the three was successful in achieving enough nitrification to meet $NH_3$-N permit limits. Surface flow cells were more adaptable and cost-effective than subsurface flow systems for handling high levels of suspended pollutants. Vegetation species did not appear to be a significant factor in overall performance under the loading conditions observed for surface flow cells. The biggest operational constraint for these systems is that solids tend to accumulate at the front of the constructed wetland cells, which results in clogging of the inlet area and reduces the effectiveness and life of the cells. Several design considerations need to be taken into account for future constructed wetlands: 1) overflow velocities should be considered in surface flow design, 2) subsurface flow design should be based on Darcy's law, 3) hydraulic conductivity values used in subsurface flow design should be relatively low, long-range values, 4) low organic loading should be used for inlet areas, 5) grading tolerances for the cells need to be within 0.1 foot.

In general, monitoring has shown that the advantages of constructed wetlands over conventional treatment processes are low capital and operating costs, pollutant removal effectiveness, flexibility to variations in organic and hydraulic load, operational and maintenance simplicity, and habitat creation for various wildlife species. In particular, potential users are attracted to the low construction cost, which is one-tenth to one-half of that needed for conventional treatment systems (Steiner et al. 1987). Disadvantages of the technology are large land requirements, lack of proven design criteria, need for additional optimization research, and the potential need for vector control when surface flow systems are used. Constructed wetlands technology is still considered to be in its developmental stages, however, because design criteria have yet to be firmly established for optimizing performance for any specific pollutant; hydraulic design of constructed wetland treatment systems is still more of an art than a science (Watson 1992). Constructed wetland systems appear to be relatively unknown and unaccepted outside the scientific community.

Cost Analysis:

Total capital costs of the Benton project are $260,000 (1987 dollars), including $250,000 for constructing the wetland and $10,000 for engineering. The capital costs of the Hardin project is $332,000 (1987 dollars), consisting of $292,000 for construction, $10,000 for land acquisition, and $30,000 for engineering. Total capital costs of the Pembroke project are $212,000 (1987 dollars), with $149,000 for construction, $35,000 for land, and $28,000 for engineering. The unit capital costs were $0.24/gpd at Benton, $2.12/gpd at Hardin, and $2.36/gpd at Pembroke. No costs were available on the monitoring program.

TABLE IV.14. Cost by Component, Municipal Wastewater Treatment by Constructed Wetlands

| Project Component | Quantity | Unit | Equipment, Materials, Supplies, etc. | Labor | Total Costs ($1994) | Total Costs ($1987) |
|---|---|---|---|---|---|---|
| Benton: 4,200 persons served | | | | | | |
| Construction of wetland | 26 | acre | Costs not given separately | | $322,843 | $250,000 |
| Engineering | 1 | LS | | | $12,914 | $10,000 |
| Subtotal, Benton | 1,100,000 | gpd | | | $335,757 | $260,000 |
| Hardin: 545 persons served | | | | | | |
| Construction of wetland | 1 | LS | | | $263,400 | $204,000 |
| Construction of hardwood storage | 1 | LS | | | $113,641 | $88,000 |
| Land | 1 | LS | | | $12,914 | $10,000 |
| Engineering | 1 | LS | | | $38,741 | $30,000 |
| Subtotal, Hardin | 100,000 | gpd | | | $428,696 | $332,000 |
| Pembroke: 1,100 persons served | | | | | | |
| Construction of wetland | 1 | LS | | | $192,415 | $149,000 |
| Land | 1 | LS | | | $45,198 | $35,000 |
| Engineering | 1 | LS | | | $36,158 | $28,000 |
| Subtotal, Pembroke | 90,000 | gpd | | | $273,771 | $212,000 |
| **TOTAL** | | | | | **$1,038,224** | **$804,000** |

Sources:

Choate, K.D., G.R. Steiner, and J.T. Watson. 1989. *First Semiannual Monitoring Report: Demonstration of Constructed Wetlands for Municipal Wastewater, March to December 1988.* TVA/WR/WQ-89/5, Tennessee Valley Authority, Chattanooga, Tennessee.

Choate, K.D., J.T. Watson, and G.R. Steiner. 1990. *Demonstration of Constructed Wetlands for Treatment of Municipal Wastewater, Monitoring Report for the Period: March 1988 to October 1989.* TVA/WR/WQ-90/11, Tennessee Valley Authority, Chattanooga, Tennessee.

Choate, K.D., J.T. Watson, and G.R. Steiner. 1993. "TVA's Constructed Wetlands Demonstration." In *Constructed Wetlands for Water Quality Improvement*, G.A. Moshiri, ed., pp. 509-516. Lewis Publishers, Boca Raton, Florida.

Knight, R.L. 1991. *Analysis of Survival and Condition of Planted Vegetation at the Benton, Hardin, and Pembroke, Kentucky Constructed Wetland Treatment Systems.* Prepared for Tennessee Valley Authority by CH2M HILL, Gainesville, Florida.

Steiner, G.R., J.T. Watson, and D.A. Hammer. 1987. "Municipal Wastewater Treatment by Constructed Wetlands: A Demonstration in Western Kentucky." In *Increasing Our Wetlands Resources*, J. Zelazny and J.S. Feierabend, eds., pp. 160-167. Proceedings of a National Wildlife Federation Conference , Washington, D.C.

Watson, J.T. 1992. *Constructed Wetlands for Municipal Wastewater Treatment: State-of-the-Art.* Presented at the Symposium Épuration Des Eaus Usées Par Les Plants: Perspectives D'Avenir au Quebec, Montreal, Quebec.

Watson, J.T., K.D. Choate, and G.R. Steiner. 1990. "Performance of Constructed Wetland Treatment Systems at Benton, Hardin, and Pembroke, Kentucky, During the Early Vegetation Establishment Phase." In *Constructed Wetlands in Water Pollution Control*, P.F. Cooper and B.C. Findlater, eds., pp. 403-410. Pergamon Press, Oxford.

## Tidal Marsh Construction, Maryland

Point of Contact:

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Project Description and Location:

From 1972 to 1993, Environmental Concern, Inc. (EC) completed 216 marsh construction projects to control upland bank erosion in tributaries of the Maryland portion of the Chesapeake Bay (Garbisch and Garbisch 1994). Of these projects, 190 used marsh construction on shores that have been restored to former increased elevations by shoreline filling and grading; the other 26 have involved marsh construction on unaltered existing shores. As a result of 21 years of experience with tidal marsh construction, EC has developed a reliable bioengineering restoration technique to control upland bank erosion, which is economically attractive compared with structural alternatives such as stone revetments and wooden bulkheads. Although the technique has only been applied in the Maryland portions of the Chesapeake Bay, it should, with modifications, be broadly applicable to other portions of the bay or other water bodies. The technique is most effective for shoreline bank erosion control when alongshore and/or offshore littoral transport or continued bank erosion supplies sufficient volumes of sand to the marsh. In such instances, the marsh vegetation effectively traps the sand, leading to an increase in shore elevation. As the shore elevation increases through sand entrapment, the frequency of contact of tidal water with the bank face decreases and the rate of bank erosion correspondingly decreases.

Project Goals/Objectives:

The objectives of the technique are the following: 1) to physically restore shores to former, higher elevations such that tidal water is excluded from the associated upland bank faces for periods of 6 to 17 years, and 2) to assure that the restored shore slopes are sufficiently stable to allow the successful construction of a sustained tidal marsh vegetation community.

Successful application of the technique can accomplish the following: 1) eliminate the loss of upland, 2) improve water quality of the associated waterbody by eliminating sediment input through bank erosion and by the treatment of stormwater runoff passing through the marsh, 3) provide habitat and food resources for fish and wildlife, 4) provide enhanced aesthetics to the owners of the treated property, and 5) provide possible long-term protection against "effective" sea level rise by virtue of the development of a peat bank over time.

Engineering Features:

Following is a summary of the recommended construction sequence:

1. Clear site to ensure at least six hours of direct sunlight daily during the growing season and to allow equipment access. Clear shore of all fallen trees and large items of debris.

2. Bring in materials and stockpile onsite. Construct full containment structures during periods of low tide.

3. Restore the shore by filling alongshore with sandy materials (greater than 90 percent should pass a No. 35 standard sieve and less than 10 percent should pass a No. 60 standard sieve) and grading (either with an excavator or hydraulically) or use alternatives that involve grading of the upland bank.

4. Construct stormwater management swales and surface containment structures where needed to minimize excessive movement of sediments during the critical vegetation establishment period.

5. Let the restored shore adjust vertically and horizontally to the prevailing wave climate for a period of two to four weeks.

6. If there are precipitation events during this adjustment period, check the restored shore for the development of stormwater erosion gullies and construct management swales, as necessary.

7. Hand grade any shore escarpments (lips) developed from shore adjustments and plant the shore (optimal time is May to June in Chesapeake Bay). If the salinity is greater than 3 parts per thousand (ppt), recommended plants are cordgrass, 18 inches on-center between midtide and 12 inches above mean high water (MHW), and saltmarsh hay 18 inches on-center starting one row past cordgrass to the toe of the bank. For water salinities less than 3 ppt, pungent bulrush and slender millet are recommended. All plants should be nursery-grown in 1.5- to 1.75-inch peat pots and have well-developed roots that extend through the sides and bottoms of the pots. Plants should be planted 3 to 4 inches below the top of the pots in order to minimize washouts due to changes in the grade of the restored shore. Fertilizer should be added: 1 fluid ounce of 3- to 4-month release Osmocote 19-6-12 fertilizer if planting during the period from May to August; 1 fluid ounce of 8- to 9-month release Osmocote 18-6-12 if planting during any other period.

8. Construct goose exclosure fence after planting the restored shore. In Chesapeake Bay region, several Canada geese can denude a newly planted shore overnight.

9. Clean, repair, and reseed all disturbed upland areas.

Steps 1 through 4 are best completed when the ground is dry or frozen.

Monitoring Techniques:

No monitoring techniques were specified. However, maintenance of the restored shore must be an ongoing commitment. The continued provision of sufficient light, the removal of litter and debris, and the control of plant disease are essential for the long-term success of the technique. Seven maintenance items are recommended to be performed by the property owner:

1. In the absence of rain, water the high elevation vegetation biweekly during the first growing season.

2. In the early spring of each year before plant growth, collect and remove all deposited litter and debris throughout the high elevations of the marsh.

3. Repair, as necessary, the goose exclosure fence for two winters following its installation.

4. Annually remove or prune tree and shrub species that could volunteer the high marsh and bank to maintain at least six hours daily of direct sunlight throughout the entire marsh.

5. In the late spring of each year, check plants for signs of rust infestation and treat as necessary.

6. Check any constructed stormwater management swales annually and remove any deposits of sand or debris in order to maintain functionality.

7. Check the entire project annually for any signs of problems such as loss of vegetation, unstable sections of restored shore, loss of sand around containment structures, scouring on the lee sides of the containment structures, new stormwater erosion gullies, and sections of continued bank erosion.

Cost Analysis:

Costs of filling, grading, and cleaning a Chesapeake Bay tidal marsh (the Garbisch technique) are estimated at $55 to $65 (1993 dollars) per foot (Table IV.15). This estimate is compared with estimates of costs of other erosion control approaches including a stone (riprap) revetment and a

wooden bulkhead. Stone revetments currently are the most commonly used approach for upland bank erosion control throughout the Chesapeake Bay and its tributaries. Bulkheads of any type are currently discouraged by the regulatory agencies.

Costs for the technique of filling and grading with no clearing equal $50 to $55 per linear foot of shoreline treated. Costs for stone revetment construction with no clearing are $60 to $65 per linear foot of shoreline treated for a revetment 3 feet high and 6 feet wide; $75 to $80 per linear foot of shoreline treated for a revetment 4 feet high and 8 feet wide. Costs for wooden bulkhead construction are $70 to $75 per linear foot of shoreline treated for a bulkhead 3 feet high; $90 to $95 per linear foot of shoreline treated for a bulkhead 4 feet high.

Clearing costs for equipment access to the shore and for shore cleanup for both the Garbisch technique and stone revetments could add $5 to $10 per linear foot to the costs given above. Such costs normally are not part of those for bulkhead construction, since this work is done from the water, and alongshore trash, litter, and debris (shore cleanup) are thrown behind the bulkhead, as necessary, and buried with fill materials. Grading of the unprotected upper bank could add additional costs to the Garbisch technique and to stone revetment construction, depending on site conditions and the extent of grading.

TABLE IV.15. Cost by Component, Chesapeake Bay Tidal Marsh

| Project Component | Quantity | Unit | Equipment, Materials, Supplies, etc. | Labor | Unit Costs ($1994) |
|---|---|---|---|---|---|
| Filling and Grading | | ft | | | $51 to $56 |
| Clearing | | ft | | | $5 to $10 |

Sources:

Garbisch, E.W., and J.L. Garbisch. 1994. "Control of Upland Bank Erosion Through Tidal Marsh Construction on Restored Shores: Application in the Maryland Portion of the Chesapeake Bay." *Environmental Management* 18(5):677-691.

## Kennedy Park Wetland Creation and Enhancement, California

Point of Contact:

Mr. Bob Carlson
P.O. Box 660
Napa, CA 94599
Phone: (707) 257-9529

Project Description, Location, and Goals/Objectives:

Kennedy Park is located adjacent to the Napa River in Napa, California. This project involved creation of a total of 10 acres of new wetland in Kennedy Park and enhancement of 3 acres of existing wetland. The primary goal was to enhance wildlife habitat values and wetland diversity at Kennedy Park without negatively affecting existing wildlife use. This goal needed to be balanced with public access, recreation, and flood control priorities. The ecological performance criteria for the enhancement project were as follows: 1) provide increased and enhanced foraging areas for shorebirds and wading birds, 2) establish tidal habitat for benthic invertebrates and juvenile fish, 3) establish areas with emergent vegetation for perching birds, and 4) create buffers between wetlands and public use.

Engineering Features:

The project was completed in 1994. Alternatives examined involved leaving or replacing a drainage culvert in order to create water circulation within the wetland area. A new 24-inch culvert was installed with a combination screw/flap gate on the outboard side of the culvert between the wetland and the Napa River. Flashboard weirs were installed on the inside of the culvert. The specific engineering features were the following:

- 24-inch RCP storm drain (105 linear feet)
- outfall system
- perimeter fencing (4,720 linear feet)
- pathway (2,700 linear feet)
- peeler core bollards
- timber retaining wall (20 linear feet)

- interpretative signs (3)
- aggregate base (240 tons)
- asphalt concrete dike (118 linear feet)
- fabric membrane (1,080 square yards).

Monitoring Techniques:

No monitoring program was established.

Cost Analysis:

The total cost of the Kennedy Park wetland restoration project is estimated to be $408,345 (1993 dollars) (Table IV.16). Costs include the design, engineering, planning, mobilization, construction, and maintenance (five hours of labor per month on an ongoing basis) of an outfall system. A 24-inch culvert was installed (combined with a screw/flap gate on the outboard side of the culvert between the wetland and the Napa River with flashboard weirs on the inboard side) to convert a 13-acre site into a viable wetland. All project component costs are reported as installed, including labor, materials, and equipment.

TABLE IV.16. Cost by Component, Kennedy Park

| Project Component | Quantity | Unit | Equipment, Materials, Supplies, etc. | Labor | Total Costs ($1994) | Total Costs ($1993) |
|---|---|---|---|---|---|---|
| 24-inch RCP storm drain | 105 | lf | $4,410 | | $4,521 | $4,410 |
| Outfall system | | LS | $25,900 | | $26,552 | $25,900 |
| Perimeter fencing | 4,720 | lf | $19,300 | | $19,786 | $19,300 |
| Aggregate base pathway | 2,700 | lf | $22,410 | | $22,974 | $22,410 |
| Peeler core bollards | 135 | ea | $2,700 | | $2,768 | $2,700 |
| Timber retaining wall | 20 | lf | $1,000 | | $1,025 | $1,000 |
| Interpretive boards | 3 | ea | $9,750 | | $9,995 | $9,750 |
| Aggregate base | 240 | tons | $3,360 | | $3,445 | $3,360 |
| Asphalt concrete dike | 118 | lf | $590 | | $605 | $590 |
| Fabric membrane | 1,080 | sy | $1,944 | | $1,993 | $1,944 |
| Clearing and grubbing | | LS | $12,602 | | $12,919 | $12,602 |
| Site excavation | | LS | $62,140 | | $63,704 | $62,140 |
| Ditch excavation | | LS | $8,160 | | $8,365 | $8,160 |
| Grading existing dike | | LS | $3,978 | | $4,078 | $3,978 |
| Maintenance | | LS | | $101 | $104 | $101 |
| Design and engineering | | LS | $200,000 | | $205,031 | $200,000 |
| Planning | | LS | $30,000 | | $30,755 | $30,000 |
| **Total** | | | **408,245** | | **$418,620** | **$408,345** |

Sources:

Project files and personal communication with Bob Carlson.

## Cowlitz Wildlife Enhancement, Rainy Creek Dike, Washington

Point of Contact:

Mr. Mick Cope
Washington State Department of Fisheries and Wildlife
600 Capital Way North
Olympia, WA 98501-1091
Phone: (360) 983-8427

Project Description, Location, and Goals/Objectives:

The Cowlitz Wildlife Mitigation project is located on land owned by Tacoma City Light in southern Washington. The goal of this project was to enhance the value of wetlands to wildlife in the following ways: 1) increasing interspersion of open waters in marsh vegetation, 2) increasing desirable vegetation species, and 3) increasing productivity (by releasing nutrients bound in bottom soils). Treatments to improve or increase wetlands were development of ponds and islands, control of water levels, seeding of hydrophytic vegetation on seasonally exposed mud flats, installation of artificial nesting structures, and disposal of accumulated woody debris. This project was planned prior to 1980 and has been the subject of ongoing management by WDFW.

A recent project within the Cowlitz Wildlife Mitigation project is the Rainy Creek Dike. The intent of this 1,000-foot dike is to create a permanent water source on the east end of Riffe Lake for 50 acres of wildlife habitat. Riffe Lake is formed behind a hydroelectric and flood control dam and must be lowered approximately 70 feet during the winter. Tacoma City Light cannot return the lake to full pool until Memorial Day. Low water inhibits nesting by waterfowl and other wetland-dependent species. During autumn, rising water floods nests, resulting in lost production.

Engineering Features:

Four types of ponds were built: 1) dugouts in meadows or shallow wetlands, 2) dugouts with islands inside the flow line of a large impoundment, 3) dugouts with dikes to catch intermittent water flows, and 4) blasted potholes. These ponds were located within 0.25 mile of larger wetlands that provide brooding and loafing areas. Islands were constructed to provide safe nesting locations for waterfowl. Expected life of the islands is 20 to 30 years. Specifications for islands were as follows:

1. diameter of island above flow line = 1 foot
2. height above flow line = 1 foot
3. slopes below water = 2:1

4. water depth at site prior to construction = 1 to 4 feet

5. dugout pond borrow pits to follow pond specifications

6. distance from shoreline = at least diameter of island

7. dredged material mounds were well compacted

8. islands placed in larger impoundments were riprapped

9. all disturbed soil above the water line was seeded with red top and yellow sweet clover.

Stabilized water levels during the growing season promote development of aquatic plants that provide food and cover for wildlife. Basic water level management is as follows:

1. Late winter/early spring--Drawdown pool gradually to minimum level to allow weather to clean shoreline of algae and silt.

2. Early spring/midsummer--Gradually raise pool to maximum; as vegetation decomposes, it adds nutrients and organic material and binds with clay, which reduces turbidity. Flooding vegetation will increase waterfowl breeding, brooding, and feeding habitat.

3. Midsummer/late summer--Lower water levels to promote exposed shoreline vegetation growth. Then, bottom soils will oxidize and release nutrients for aquatic vegetation growth.

Control structures are site specific and vary with impoundment size and volume of water to be controlled. Seeding of quickly sprouting grasses or grains was used on moist mudflats to improve water quality and produce food for fish and wildlife. Three hundred acres of mudflats were seeded with annual ryegrass by helicopter.

At Rainy Creek, an impoundment will be created by a 1,000-foot-long dike. The impoundment will be approximately 50 acres in size and have a depth that varies from 0 to 12 feet. Rain will initially provide water to the impoundment. Water fluctuation control will be implemented, if needed, by installing a well.

Monitoring Techniques:

Monitoring techniques were not specified. Cowlitz project wetlands provided critical habitat for 61 species of wildlife, which rely solely on water/wetland habitats for reproduction. Wetlands also provided feeding habitats for many other species, such as coot, goldeneye, bald eagle, osprey, great blue herons, red-winged blackbirds, muskrat, mink, and beaver.

Cost Analysis (Rainy Creek Dike only):

The cost of the Rainy Creek Dike project is estimated at $200,000 (1993 dollars) ($200 per linear foot or $4,000 per acre), including supporting engineering, soils and hydrologic consulting, permits, and contingency (Table IV.17). Excavation is estimated at $58,200 ($5.20 per cubic yard), riprap at $60,000 ($30.00 per cubic yard, installed), a walkway and flashboard riser (outlet structure) at $18,000, and a filter drain at $2,546, for a total of $138,746. Consultants, engineering, and permits come to a combined $30,200. Monitoring, maintenance, and future project enhancements, though they will occur, have not been costed.

Table IV.17. Cost by Component, Rainey Creek Dike/Cowlitz Project Wildlife Mitigation

| Project Component | Quantity | Unit | Equipment, Materials, Supplies, etc. | Labor | Total Costs ($1994) | Total Costs ($1993) |
|---|---|---|---|---|---|---|
| Excavation for dike construction | 11,200 | cy | Costs not provided separately | | $59,664 | $58,200 |
| Riprap material and installation | 2,000 | cy | | | $61,509 | $60,000 |
| Outlet structure walkway and flashboard riser | 1 | LS | | | $18,453 | $18,000 |
| Filter drain material and installation | 1 | LS | | | $2,610 | $2,546 |
| Subtotal | 1,000 | lf | | | $142,236 | $138,746 |
| Permits, engineering, planning | | | | | | |
| Consultants, hydrology and soils | 1 | LS | | | $12,302 | $12,000 |
| Permits (Ecology) | 1 | LS | | | $3,281 | $3,200 |
| Engineering: specifications and plans | 1 | LS | | | $15,377 | $15,000 |
| Subtotal | | | | | $30,960 | $30,200 |
| Other | | | | | | |
| State sales tax | 1 | LS | | | $2,738 | $2,671 |
| Contingency (10% of subtotal) | 1 | LS | | | $17,320 | $16,895 |
| Subtotal | | | | | $20,058 | $19,566 |
| **Total** | | | | | **$193,254** | **$188,512** |

Sources:

Rainy Creek Dike cost estimate from by Mr. Nick Cope, Cowlitz Wildlife Area, March 30, 1995.

## Roberts Landing Wetland Enhancement, California

Point of Contact:

Dr. Robert Coates
Phillip Williams & Associates, Ltd.
Pier 35, The Embarcadero
San Francisco, CA 94133
Phone: (415) 981-5021

Project Description, Location, and Goals/Objectives:

The City of San Leandro and Citation Homes Central have developed a restoration and enhancement plan for a 300-acre area near Roberts Landing Slough at San Leandro, California. The plan was developed over a period of three years with minor revisions in response to agency review and comments (Coats 1993).

This plan was developed in two modules. The modules have been designed to be carried out as one integrated plan, but either could be done without the other. The first module, for the City of San Leandro, treats 172 acres of land owned by the State of California and administered by the California State Lands Commission (SLC). The second module, designed for Citation Homes, treats 106 acres of land owned by that company. This plan is a part of a residential project planned for about 80 acres which border the SLC property. The goal was developed to mitigate for the proposed filling of 13 acres of non-tidal wetland.

Implementation for Module 1 is required as a condition of approval for the Corps permit authorizing dredging for the city's marina. San Leandro's plan was developed with participation of the SLC staff, USFWS, California Department of Fish and Game (CDFG), Alameda County Flood Control and Water Conservation District, and the Alameda County Mosquito Abatement District. The hydrologic elements of both modules were developed by Philip Williams and Associates. The plan for Module 2 was developed with input and review from the Corps, EPA, USFWS, CDFG, Regional Water Quality Control Board (RWQCB), and the SLC.

Engineering Features:

The following summarizes the proposed engineering features of the City of San Leandro's portion of the project:

1. excavate a 1,500-foot channel from San Lorenzo Creek to the Bunker Marsh

2. excavate a 3,100-foot channel from Roberts Landing Slough to Bunker Marsh

3. remove accumulated woody and plastic debris from Roberts Landing Slough
4. install a 2-foot-diameter culvert from Roberts Landing Slough into the East Marsh
5. rip or disk areas in the East Marsh, in order to encourage the growth of pickleweed
6. repair and restore the levee between the East Marsh and Roberts Landing Slough
7. install four 4-foot-diameter culverts between the Bay and the North Marsh
8. excavate interior channels to improve circulation in the North Marsh
9. create five islands in the North Marsh with material excavated from the new channels
10. open (if necessary) a pilot channel across the mudflat to allow the North Marsh culverts to drain freely into the bay
11. improve the existing public access path.

The following summarizes the proposed engineering features of the Citation Homes portion of the project:

1. enlarge the Roberts Landing Slough channel
2. install 4-foot-diameter culverts in a riprapped levee and remove a timber bridge
3. reduce the elevation of the levee between Bluebird Marsh and the North Marsh
4. excavate fill material from the Bluebird dumpsite to enhance the wetland value
5. excavate new channels in the Bluebird Marsh
6. install two 3-foot-diameter culverts between Bluebird Marsh and Estudillo Canal
7. construct refuge islands in North Marsh using materials from lowering the levee and from channel excavation.

<u>Monitoring Techniques</u>:

No monitoring has been performed yet. The restoration and enhancement plan requires that monitoring, management, and maintenance be carried out for a minimum of five years to assess restoration progress and verify satisfaction of enhancement objectives (Coats 1993). Specific

performance criteria have been developed to monitor the success of hydrologic, sedimentation, and vegetation features of the plan with specific corrective measures, such as replanting and rechanneling. Salt marsh harvest mice will be trapped, birds counted, and salinity tested regularly to measure success of the plans. Recording gauges will be used to compare measured actual tide heights with modeled tide heights, thus allowing periodic "fine tuning" of the system. Monument cross sections will be surveyed and resurveyed to measure scour or deposition of sediment.

Sources:

Coats, R. 1993. *Technical Memorandum for the Roberts Landing Wetland Enhancement Plan.* Prepared by Phillip Williams & Associates, Ltd., San Francisco, California.

## San Leandro Shoreline Marshlands Enhancement Project, California

Point of Contact:

Mr. Andrew Leahy
562 16th Avenue
San Francisco, CA 94118
Phone: (415) 386-5893

Project Description, Location, and Goals/Objectives:

The Marshlands Enhancement Project was designed to restore either full or partial tidal action within three areas, encompassing a total area of approximately 140 acres along the San Leandro Shoreline between the Tony Lema Golf Course and San Lorenzo Creek, San Leandro, California. Virtually the entire shoreline area currently supports sensitive marsh or wetland habitat that will be protected throughout project construction. Material excavated from existing tidal channels will be used for construction of new marsh islands within the North Marsh.

Engineering Features:

The Marshlands Enhancement Project also includes improvement of existing trails and maintenance roads, construction of new emergency vehicle access routes and trails extensions, restoration of a portion of an existing deteriorated San Francisco Bay levee, removal of accumulated driftwood within specified marsh areas, and miscellaneous items of shoreline maintenance. The specific engineering that was carried out for this project is as follows:

- excavate new slough channels and improve existing channels
- excavate borrow material from City of San Leandro Dredged Material Management Site
- construct habitat islands within the North Marsh using channel excavation spoils and dredged material management site borrow material
- furnish and install four 48-inch-diameter by 65-foot-long ductile iron pipe inlet culverts
- construct a concrete control structure with combination flap/sluice gates on culverts
- construct concrete headwall and riprap slope protection at the North Marsh Bay levee
- backfill and restore the existing levee, and install a dewatering cofferdam

- furnish and install 24-inch-diameter by 30-foot-long inlet culvert and sluice gate, and construct operating platform and riprap slope protection at the East Marsh Roberts Landing Slough levee

- improve existing 14-foot-wide by 2,300-foot-long Public Access Trail/Emergency Access Road between the southerly end of Shoreline Trail and the westerly end of Lewelling Boulevard extension

- clear obstructions and correct grade deficiencies (place 400 tons aggregate base) along existing 4,900-foot-long segment of existing Shoreline Trail/Maintenance Road between Estudillo Canal and the southerly end of the Shoreline Trail

- clear and rough grade 14-foot-wide by 2,100-foot-long Public Access Trail south from Lewelling Boulevard Extension to the San Leandro Creek levee

- repair and stabilize an approximately 200-foot-long section of deteriorated, 3-foot-high bay-front levee adjacent to Bunker Marsh

- raise and grade an approximately 9-foot-wide by 900-foot-long section of the existing Roberts Landing Slough levee adjacent to the East Marsh

- remove and dispose of all driftwood and debris within the designated area of the existing Roberts Landing Slough

- remove and dispose of all driftwood, construction materials, asphalt concrete rubble and debris from existing and proposed marsh channels that are to be excavated as part of this project

- excavate in place soil at four designated locations and dispose of all excavated soils at an approved, offsite dump or landfill

- furnish and install sign posts and sign supports and install five Shoreline Trail signs furnished by the City

- furnish, install, maintain and remove site security fencing, temporary signs and barricades

- patrol site 24 hours/day during construction

- remove existing abandoned culverts

- regrade and restore all disturbed areas upon completion of construction.

Monitoring Techniques:

This project is still in the implementation phase. No monitoring has been performed yet.

Cost Analysis:

The San Leandro Shoreline Marshlands Enhancement Project was begun in March 1994 and completed in February 1995 at a final total cost of $980,000 (1994 dollars) (Table IV.18) (somewhat more than the winning low bid of $918,000). The engineering firm separately charged about $55,000 for engineering services. The City of San Leandro did its own inspection.

Tidal channels were excavated (17,000 cubic yards at a cost of $300,000), old culverts removed at a cost of $7,000 and new culverts and control structures were installed at a cost of slightly less than $300,000. Virtually the entire shoreline area currently supports sensitive marsh or wetland habitat that had to be protected and preserved throughout project construction. The bidder had to become familiar with environmental constraints on performing the project. Among these requirements was that borrow material came from the San Leandro Dredged Material Management Site at a cost of $80,000 ($6.71 per cubic yard); that disposal of driftwood, construction materials and rubble from marsh channels had to be removed (cost of $38,400); and that some excavated soils be removed to an approved offsite landfill.

## TABLE IV.18. Cost by Component, San Leandro Shoreline

| Project Component | Quantity | Unit | Equipment, Materials, Supplies, etc. | Labor | Total Costs ($1994) |
|---|---|---|---|---|---|
| Excavate new slough channels | 17,000 | cy | | | $300,000 |
| Excavate borrow material from dredged material management site | 10,600 | cy | | | $80,000 |
| Construct 5 habitat islands | 21,000 | cy[a] | | | |
| Furnish and install 4 culverts, 48-inch diameter | 65 | lf ea | | | $287,000 |
| Furnish and install culvert (24-inch diameter) and sluice gate | 30 | lf ea | | | $11,500 |
| Improve access roads, 14-feet wide | 2,300 | lf | | | $46,000 |
| Clear obstructions and revise grades | 4,900 | lf | | | $26,600 |
| Clear and grade access trail, 14-feet wide | 2,100 | lf | | | $16,000 |
| Repair levee, 3-feet high | 200 | lf | | | $4,000 |
| Raise existing Roberts Landing Slough levee (9-feet wide) to grade | 900 | lf | | | $6,300 |
| Excavate and legally dispose of soil | 95 | cy | | | $1,500 |
| Furnish and install access signs | 5 | ea | | | $1,000 |
| Security | 1 | LS | | | $3,500 |
| Remove abandoned culverts | 1 | LS | | | $7,000 |
| Mobilization and miscellaneous | 1 | LS | | | $90,000 |
| Remove and dispose debris | 1 | LS | | | $38,400 |
| **Total** | | | | | **$918,800** |

(a) Cost included in excavation costs.

Sources:

Project files and personal communication with Andrew Leahy.

## Triangle Marsh, California

Point of Contact:

Mr. Owen Williams
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Mr. Michael Koslosky
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Dr. Robert Coats
Philip Williams & Associates
Pier 35, The Embarcadero
San Francisco, CA 94133
Phone: (415) 981-8363

Project Description and Location:

In 1987, the Schnitzer Steel Products Company, Inc., was allowed to fill 1.3 acres of subtidal land in Oakland, California. As mitigation, the company agreed to enhance about 7 acres of partially tidal wetland (Triangle Marsh) at Hayward, California. Triangle Marsh is located at the west end of West Winton Avenue, on the north side of a former landfill site known as Mt. Trashmore. The marsh is partially isolated by levees, a road, and a flood control channel. Much of the marsh contained dead or dying pickleweed. It was suspected that the condition of the plants was due to very high soil salinites associated with the restricted nature of tidal flow in the system. The associated Buffer Pond and "panhandle marsh" also had been disturbed by levee and road construction, restricted tidal flow and human activity.

Project Goals/Objectives:

The enhancement goals were as follows: 1) enhance the biological productivity and habitat diversity of the site; 2) enhance water quality in the Triangle and Buffer Pond; 3) reduce breeding opportunities for mosquitoes; and 4) prevent flooding by high tides of a storage area and office at the west end of West Winton. The species identified for enhancement were salt marsh harvest mouse, salt marsh song sparrow, California clapper rail, black rail, and other shorebirds, waterfowl, heron and egret.

The recommended alternative to meet the stated goals was to enhance drainage in a pond and to enhance ponding in another pond. This alternative was recommended because it provides greater habitat diversity and would retain more water at low tide. In addition, circulation and water quality would be improved. Construction was completed in 1990.

Engineering Features:

The engineering features for the enhancement plan consisted of the following:

- installation of two 3-foot-diameter culverts with slide/flap gates, connecting the marsh to the bay
- installation of new interior culverts at three locations
- enlargement of existing channels and excavation of new ditches to improve circulation
- creation of a small pond at the end of the panhandle to provide a refuge for small fish at low tide.

Monitoring Techniques:

A five-year monitoring program was initiated in 1991 to study hydrology, sedimentation, vegetation, birds, benthic invertebrates, and water-column fish and macroinvertebrates. Hydrology (i.e., tidal fluctuation) was measured using two recording tide gauges. Sedimentation was estimated by surveying six cross-sections of channels and resurveying these cross-sections periodically. Vegetation was monitored by taking panoramic photographs monthly from nine fixed stations in the marsh. Birds were counted during 10 (1- to 1.5-hour long) surveys between August and April. Benthic invertebrates were sampled using a 3-inch-diameter by 4-inch-deep core at six points in the system on three dates between August and April. Fish and macroinvertebrates were sampled with seines at two sites. After two years, the tidal flushing and other features have resulted in higher vigor of marsh vegetation, the occupation of the site by shorebirds and waterfowl, and the transient use of the site by fish and macroinvertebrates.

Cost Analysis:

The total cost of the Triangle Marsh habitat enhancement project is $134,123 (1990 dollars) (Table IV.19). Costs are the installation of six culverts (two 3-foot, two 2-foot, and two 18-inch), engineering, planning and design, and a five-year monitoring program.

TABLE IV.19. Cost by Component, Triangle Marsh

| Project Component | Quantity | Unit | Equipment, Materials, Supplies, etc. | Labor | Total Costs($1994) | Total Costs ($1990) |
|---|---|---|---|---|---|---|
| Planning/study | | LS | | | $12,343 | $10,997 |
| Engineering plans | | LS | | | $5,520 | $4,918 |
| Monitoring | | LS | | | $31,336 | $27,918 |
| Culvert installation | 6 | ea | $21,390 | $68,900 | $101,343 | $90,290 |
| **Total** | | | **$21,390** | **$68,900** | **$150,542** | **$134,123** |

Sources:

Coats, R., and L. Posternak. 1988. *Enhancement Plan for the Triangle Marsh at Hayward.* Report to the Hayward Area Park and Recreation District. Phillip Williams & Associates, San Francisco, California.

Coats, R., E.B. Lyke, and M. Josselyn. 1992. *Triangle Marsh Monitoring Report No. 1.* Phillip Williams & Associates, San Francisco, California.

Coats, R., E.B. Lyke, and W. Carmen. 1993. *Triangle Marsh Monitoring Report No. 2.* Phillip Williams & Associates, San Francisco, California.

## Cascade Crossings Wetland Mitigation Project, Michigan

Point of Contact:

Dr. Ronald F. Brown
Resource Management Group, Inc.
P.O. Box 1122
Big Rapids, MI 49307-1122
Phone: (906) 789-1133

Project Description, Location, and Goals/Objectives:

The objective of this project was to create 66 acres of compensatory wetland mitigation on an 80-acre parcel near Sault Ste. Marie, Michigan. The wetland mitigation project was designed to compensate for the loss of 22 acres of wetlands permitted to be altered at a proposed shopping center site. The mitigation site is within five miles of the shopping center site in Soo Township, Chippewa County, Michigan. The created wetland is intended to function primarily in support of waterfowl, with complementary habitat for other species of wildlife and aquatic organisms. Secondary goals included flood storage, water quality improvement through nutrient uptake and sediment filtration, and upland wildlife habitat (14 acres). Compensatory mitigation was required by the Michigan Department of Natural Resources (MDNR) at a 3:1 (created:impacted) ratio as a condition of the permit (No. 90-4-48W). Other agencies involved were USFWS, EPA, and the Corps. Both on- and offsite mitigation alternatives were evaluated. Off-site mitigation was selected. On-site mitigation was not feasible because of the amount of acreage required by the regulatory agencies, the lack of onsite space, and the unavailability of a suitable site in relatively close proximity to the development project site. Design considerations for the mitigation wetland were MDNR draft permit conditions, existing topographical features, engineering considerations, biological/ecological concepts, and construction cost and feasibility.

Engineering Features:

The mitigation wetland complex was created between September 1992 and October 1993. Engineering features were two earthen berms (total 6,400 linear feet), two concrete spillways, and two riprap spillways (RMG 1992). Earth quantities required for berm construction were balanced with excavation quantities to avoid unnecessary disposal of excess material offsite. The berms were constructed, using Pickford soils that occur onsite, to retain surface water runoff at a designed elevation. Rudyard soils, which were less desirable for berm construction, were used for topdressing the berms to create final grades. Physical alterations to the site involved excavation to provide permanent water pools (1 to 2 feet deep) that would add habitat diversity and encourage use by wildlife, and low-flow channels that were excavated to route water through the system and ensure maximum retention time. The overall hydrologic design objective was to capture all available runoff

in the wetland mitigation site, promote maximum water circulation, and provide adequate emergency overflows to protect the integrity of the berms in case of severe storm events. Specific access points for construction equipment were identified in advance of any earthwork. Silt fences and access barriers were installed as specified in the soil erosion plan. There were no maintenance requirements for physical conditions or structures. The wetland system is buffered by existing upland at the perimeter. Native vegetation was planted to enhance the wildlife habitat value of the existing upland buffer, provide preferred, indigenous wetland food and cover, discourage vehicular access to the berms, and trap snow to provide additional water recharge to the system. Upon completion of final grading, all berms were hydroseeded with a perennial grass mixture adapted for growth in the soil and moisture regime on the site. Nesting structures (12 wood duck nest boxes, four concrete culvert nesting structures) were placed at strategic locations within the site. Loafing logs were also provided as resting structures for turtles, frogs, and ducks.

Monitoring Techniques:

As required in the MDNR permit, the wetland mitigation site will be evaluated each year for a period of five years. Resource Management Group (RMG) recently completed the first year monitoring report (RMG 1994). Year 1 monitoring was designed to evaluate the ecological performance criteria for the mitigation wetland, which were as follows:

1. establish 66 acres of self-sustaining wetland and 14 acres of adjacent upland

2. create or preserve a diversity of vegetative communities as follows:

    a. 16 acres of native grassland (wetland and upland)
    b. 12 acres of saturated sedge meadow
    c. 40 acres of seasonally flooded emergent wetland
    d. 12 acres of semipermanently flooded wetland

3. within three growing seasons, document nesting by waterfowl and use of the wetland for brood-rearing

4. within three growing seasons, document use of the wetland by amphibians and invertebrates

5. within three growing seasons, document use of the wetland by other wildlife species, such as songbirds, shorebirds, reptiles, or furbearers.

A performance bond of $300,000 dollars is to be held in force until the MDNR certifies that the mitigation system has become a self-sustaining wetland in accordance with the ecological performance criteria.

Year 1 monitoring entailed a combination of techniques, as follows: adapted wetland determination methods from the U.S. Army Corps of Engineers Wetland Delineation Manual, 1987 edition; quantitative transect and quadrat (one square meter [1.196 square yards]) vegetation sampling; qualitative vegetation sampling; photo documentation from established reference points; aerial photo documentation; and current waterfowl use sampling techniques, which were independently applied by a graduate student from Michigan State University. Wildlife observations were made on a weekly basis from May to August, with an intensive nest search effort. Staff gauge readings were recorded at three gauges on a weekly basis from May through July and at periodic intervals thereafter. Six permanent vegetation sampling transects were established and soils were sampled at each typical vegetation community. Vegetation sampling was performed twice in 1994, with correspondent observations of site use by reptiles, amphibians, and aquatic invertebrates.

The first year monitoring report does not attempt to predict the success or derive any conclusions regarding the long-term viability of the wetland creation/restoration. However, results from the first year monitoring indicate that wetland hydrology has been restored at the site, providing a variety of habitat types. Intensive wildlife monitoring also indicated that 11 waterfowl species, as well as a number of wading birds, shorebirds, mammals, amphibians, and aquatic invertebrates, are using the system throughout the year. RMG anticipates that subsequent monitoring reports will chronicle the evolution of plant communities in response to the wetland hydrology establishment.

Cost Analysis:

The Cascade Crossings Wetland Mitigation project cost a total of $537,660 (1992 dollars) (Table IV.20) to construct. Separate costs were not available for the 6,400 linear feet of earthen berm, two concrete spillways, and two riprap spillways. The property owner was paid $25,000; the engineering, design, and contractor permitting activities cost $30,000; and the planning of the project by the Resource Management Group, Inc., cost $45,000. The project was designed to require little or no maintenance. The five-year monitoring program is expected to cost $71,598. Total of all costs, including monitoring, is expected to be about $538,000 for 66 acres, or about $8,150 per acre.

TABLE IV.20. Cost by Component, Cascade Crossings Wetland Mitigation

| Project Component | Quantity | Unit | Equipment, Materials, Supplies, etc. | Labor | Total Costs($1994) | Total Costs ($1992) |
|---|---|---|---|---|---|---|
| Project engineer planning, permitting | | | | | | |
| Planning-Resource Management Group | 1 | LS | | $45,062 | $47,118 | $45,062 |
| Engineering Design | 1 | LS | | $30,000 | $31,368 | $30,000 |
| Construction | 1 | LS | $350,000 | | $365,966 | $350,000 |
| Remediation | 1 | LS | $16,000 | | $16,730 | $16,000 |
| Compensation to property owner | 80 | acre | $25,00 | | $26,140 | $25,000 |
| Subtotal | | | $391,000 | $75,062 | $487,322 | $466,062 |
| Monitoring | 5 | years | $0 | $71,598 | $74,864 | $71,598 |
| **Total** | | | **$391,000** | **$146,660** | **$562,186** | **$537,660** |

Sources:

RMG (Resources Management Group). 1992. *Final Wetland Mitigation Plan for Cascade Crossings, Sault Ste. Marie, Michigan.* Prepared for RG Properties by Resources Management Group, Inc., Escanaba, Michigan.

RMG (Resources Managment Group). 1994. *Cascade Crossings Mitigation Site Wetland System Monitoring Report.* Prepared for Michigan Department of Natural Resources by Resources Management Group, Inc., Escanaba, Michigan.

**Indian River Boulevard North Extension Project, Florida**

Point of Contact:

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Project Description and Location:

Indian River County, Florida, constructed an extension of Indian River Boulevard as a public use roadwork project. Since the extension affected approximately 10 acres of wetlands (out of a 100-acre impounded wetland), it was necessary for Indian River County to mitigate for this wetland loss. These wetlands had been previously affected through the creation of a mosquito control impoundment in 1956, and more recently, with the invasion of exotic vegetation. The mitigation plan that was accepted involved the restoration of the remaining impounded marsh (approximately 90 acres) to a more functional, tidal status with the implementation of a rotational impoundment management (RIM) plan and with the elimination of the exotic plants.

Project Goals/Objectives:

The goals of the RIM plan were the following: 1) to provide economical and effective mosquito control in an area that was becoming more difficult to manage; 2) to enhance natural resources by restoring tidal connection to the lagoon system on a seasonal basis; 3) to improve water quality; and 4) to control/remove exotic vegetation within the impoundment.

Engineering Features:

The restoration work, which was undertaken in 1992 and 1993, included the installation of seven exchange culverts, two internal culverts, and a permanent, 6,000 gallons/hour (gph) electric pump. Virtually no dredging or filling was done as part of this project. No serious problems were encountered during the construction phase other than the typical difficulty of working in wetlands (i.e., soft soils contribute to the awkward handling of heavy equipment). The wetlands are now flooded in the summer for mosquito and exotic plant control, and culverts are opened for the remainder of the year for marsh/estuary exchange benefits.

Monitoring Techniques:

An operating permit requires the Indian River Mosquito Control District (IRMCD) to monitor water quality parameters (temperature, salinity, pH, turbidity, and dissolved oxygen) on a monthly basis. The permit also specifies certain time periods when culverts may be closed or must be opened and limits the flooding elevation for mosquito control.

Although more detailed biological surveys have been required as part of the mitigation in the past, the widespread acceptance of RIM over the last several years has precluded the need for additional studies or monitoring.

The effectiveness of monitoring and assessing performance is highly variable. For some criteria (e.g., die-back of exotics), periodic review is sufficient. A review of exotic coverage once per year would be sufficient to determine changes in percentage of coverage, health of exotics, among other parameters. This can also be applied to mitigation sites that include plantings as part of the mitigation. A once-per-year site review would be sufficient to determine percentage of coverage and to document whether the planting has reached the minimum coverage requirements. Other monitoring, specifically of water quality, must be done on a more intensive basis. There are countless factors that can influence water quality that represent only short-term changes and are not truly indicative of the overall health of the system. For example, several days of clouds and rain can give a low dissolved oxygen reading that is only a temporary drop in water quality, whereas several days of windy weather can result in an unusually high oxygen reading, thereby conveying a false impression of excellent water quality. There can also be significant changes based on sampling site variables, with sites in close proximity showing varied water quality results depending upon openness versus shade, water depth, circulation, and other factors. And finally, time of day can be a critical factor in water quality monitoring, with significant changes occurring between morning and afternoon samples.

Understanding the natural characteristics of the habitat where the mitigation is being performed is very important. An impounded marsh, which was historically a high marsh infrequently flooded by normal lagoon tides, has water quality parameters extremely different from those of open water bodies, such as the lagoon. These historic high marshes were generally harsh environments, with isolated ponds and tidal creeks reaching extreme levels of salinity, temperature, and oxygen. There has been some work done that shows that juveniles of certain species can tolerate much poorer water quality levels than their adult relatives, thus providing a measure of protection from predators.

Therefore, in the case of this project, emphasis was placed more on the background work and development of a biologically and technically sound plan than on post-project monitoring. While certainly some post-project monitoring is necessary, the great majority of resources should be spent in planning and implementation. A well-designed and well-implemented project will probably have a much greater success rate than a poorly designed and carelessly implemented, whether or not heavily monitored, project.

Within the context of this survey, the project is progressing well. Water quality has been satisfactory, and mosquito production has been controlled with a minimum of chemical applications. Exotic die back has occurred in most low lying areas of the marsh, although there are still some exotics on high spoil ridges within the marsh that will probably need to be removed by hand.

Cost Analysis:

The cost of the Indian River County mitigation project (the restoration of 90 acres of impounded marsh using a rotational improvement management plan) is $86,600 (1993 dollars) (Table IV.21). Costs include the installation of 11 culverts 20 to 30 feet in length, a permanent 6,000 GPH pump station, legal services, engineering (the development of an impoundment management plan), design of the electric pump station, and miscellaneous expenses. Component costs are all reported as installed costs (including labor, material, and equipment).

TABLE IV.21. Cost by Component, Indian River Boulevard

| Project Component | Quantity | Unit | Equipment, Materials, Supplies, etc. | Labor | Total Costs ($1994) | Total Costs ($1993) |
|---|---|---|---|---|---|---|
| Culvert installation | 11 | ea | $18,253 | | $18,712 | $18,253 |
| Pump station installation | | LS | $32,544 | | $33,363 | $32,544 |
| Engineering and management plan | | LS | $34,939 | | $35,818 | $34,939 |
| Legal cost | | LS | $650 | | $666 | $650 |
| Miscellaneous cost | | LS | $214 | | $219 | $214 |
| **Total** | | | **$86,600** | | **$88,778** | **$86,600** |

Sources:

Carlson, D.B., and J.D. Carroll Jr. 1985. "Developing and implementing impoundment management methods benefiting mosquito control, fish and wildlife: a two year progress report about the Technical Subcommittee on Mosquito Impoundments." *Journal of the Florida Anti-Mosquito Association* 56:24-32.

Carlson, D.B., and P.D. O'Bryan. 1988. "Mosquito production in a rotationally managed impoundment compared to other management techniques." *Journal of the American Mosquito Control Association* 4:146-151.

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Gilmore, R.G. 1984. *Fish and macrocrustacean population dynamics in a tidally influenced impounded subtropical salt marsh.* Final Report, Florida Department of Environmental Regulation-CZM 43, Florida. 35 pp.

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Gilmore, R.G., D.J. Peters, J.L. Fyfe, and P.D. O'Bryan. 1986. *Fish, macrocrustacean and avian population dynamics in a tidally influenced impounded subtropical salt-marsh.* Final Report, Florida Department of Environmental Regulation-CZM 73,93, Florida 25pp.

O'Bryan, P.D., D.B. Carlson, and R.G. Gilmore. 1990. "Salt marsh mitigation: An example of the process of balancing mosquito control, natural resource, and development interest." *Florida Science* 53:189-203.

Provost, M.W. 1977. "Source reduction in salt-marsh mosquito control: past and future." *Mosquito News* 37:689-698.

## Sweetwater Marsh Mitigation, California

Point of Contact:

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San Diego State University
San Diego, CA 92182-0413
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Project Description and Location:

The Sweetwater River wetlands complex encompasses the largest remaining emergent wetland habitat in San Diego Bay, California. To mitigate for direct loss of wetlands in the Sweetwater complex resulting from construction of State Highway Route 54, the widening of Interstate Highway 5, and the construction of a flood control channel on the Sweetwater River, California Department of Transportation (Caltrans) is constructing and enhancing intertidal salt marsh habitat within the city of Chula Vista. The mitigation marshes include the "Connector Marsh," which was constructed as a hydrologic link between Paradise Creek and the Sweetwater complex, and Marisma de Nacion, a 17-acre marsh excavated from the "D Street fill" in early 1990. The Sweetwater Marsh mitigation project is the largest and most controversial on San Diego Bay (Pacific Estuarine Research Laboratory 1990).

Project Goals/Objectives:

USFWS issued a Biological Opinion determining that the highway and flood control projects were likely to jeopardize the continued existence of several endangered species--California least tern, light-footed clapper rail, and saltmarsh bird's beak--through direct, indirect, and cumulative impacts to the Sweetwater River wetland complex. Therefore, the Federal action agencies determined that the created wetland design should include tidal channels to provide foraging for the California least tern and light-footed clapper rail; low and middle saltmarsh for foraging and nesting areas for the light-footed clapper rail; high saltmarsh refugia for the rail; and establishment of saltmarsh bird's beak.

USFWS established the following performance criteria for the created wetland:

1. Demonstrate that the channels and emergent wetlands provide suitable, functional habitats for the California least tern and light-footed clapper rail

- the channels shall be considered to provide habitat for the tern and rail upon documenting that fish and invertebrate forage items for these species provide, for two years, 75 percent of the density and diversity of the prey base in an existing wetland in the Sweetwater River wetlands complex that does provide habitat for the tern and/or the rail

- the emergent wetlands shall be considered to provide adequate habitat for the light-footed clapper rail upon documenting that seven home ranges (i.e., nonoverlapping areas two to four acres in size) composed of low, middle, and high saltmarsh have been established for two years

- the low saltmarsh shall comprise at least 15 percent of this mix and have at least a 50 percent cover of cordgrass; the lower marsh in each home range shall also have at least one patch of cordgrass, with the following characteristics: stem length of 60 to 80 centimenters (23.6 to 31.5 inches); provision of 90 to 100 percent cover; patch size of 90 to 100 square meters (107.6 to 119.6 square yards); demonstrated duration in place for three years; and proven nitrogen fixation capability

- the middle saltmarsh shall provide at least 70 percent cover, and contain 75 percent of the native species typically found in this zone in a comparable wetland in the Sweetwater River wetlands complex

- the high saltmarsh standard is given below.

2. Show that the emergent wetlands are vegetated by patches of saltmarsh bird's beak and 75 percent of the native species currently occurring in the Sweetwater River wetlands complex

   - the emergent wetlands shall be considered successful when at least 15 percent of the habitat is high saltmarsh, with less than 10 percent cover from weedy species, and contains patches of saltmarsh bird's beak for at least two years

   - saltmarsh bird's beak shall be considered to be present when there are at least five separate patches of this species, each measuring one square meter (1.196 square yards), containing at least 20 individual plants, separated from each other by at least 10 meters (10.94 yards), and shown to be self-sustaining for three years.

Engineering Features:

The two primary engineering features were excavation of channels and placement of fill to create a tidal marsh system associated with a highway/flood control project in San Diego County.

Monitoring Techniques:

Monitoring was based on comparative studies designed to evaluate the functional equivalency between the created wetlands and existing reference wetlands in the Sweetwater River wetlands complex. Although monitoring studies are not yet complete, results are available for soils, nutrients, vegetation, and epibenthic invertebrates. Comparisons of fishes, channel benthos, and birds are in progress.

Based on soil, nutrient, vegetation, and epibenthos data, the constructed marsh was less than 60 percent functionally equivalent to the reference wetland, Paradise Creek Marsh (Pacific Estuarine Research Laboratory 1990). Inclusion of preliminary data on fishes, channel benthos, and birds failed to increase the overall similarity. Light-footed clapper rail, for which the constructed marsh was designed, were not yet using the constructed marsh. A major difference between the constructed and natural sites is the complete inundation of cordgrass in the constructed marsh during high tides. In comparison, tall cordgrass in the natural marsh extends above the water, providing a refuge for terrestrial arthropods and cover for birds hiding among the plants. Significant differences in substrate characteristics help to explain why transplanted cordgrass is growing poorly in the constructed marsh.

Sources:

National Research Council. 1992. *Restoration of Aquatic Ecosystems.* National Academy Press. Washington, D.C.

Pacific Estuarine Research Laboratory. 1990. *A Manual for Assessing Restored and Natural Coastal Wetlands with Examples from Southern California.* California Sea Grant Report No. T-CSGCP-021, La Jolla, California.

## Christmas Tree Marsh Restoration/Canal Closure Project--Barataria-Terrebonne National Estuary Program, Louisiana

Point of Contact:

Marnie Winter
Jefferson Parish Environmental & Development Control Department
1221 Elmwood Parkway, Suite 703
Harahan, LA 70123
Phone: (504) 736-6440

Project Description and Location:

The purpose of the Christmas Tree Marsh Restoration/Canal Closure Project is to establish a floating mat marsh that over the long term will fill in the entire water column in the Goose Bayou area of the Barataria-Terrebonne Estuarine Complex. This demonstration project is designed to determine the feasibility, costs, and timetables for converting three dead-end abandoned oil canals to marsh by using discarded Christmas trees.

The following agencies and local entities were involved in this project: EPA's Barataria-Terrebonne National Estuary Program (NEP); Louisiana Department of Natural Resources, Coastal Restoration Division; U.S. Coast Guard; Louisiana Department of Wildlife and Fisheries; the Corps; Louisiana Air National Guard; National Park Service; Texaco, Exxon, and other companies that donated lunches for volunteers; and volunteers from sportsmen's clubs, civic associations, environmental advocacy groups, metropolitan area high schools, Boy Scouts, and Girl Scouts.

Project Goals/Objectives:

The goals of the project are the following: 1) to convert dead-end, abandoned oil canals to marsh habitat; 2) to recycle discarded Christmas trees and provide an alternative to placing them in landfills; 3) to study type and duration of the fertilizer needed to speed up the natural process; and 4) to educate the public on recycling, scarcity of landfill space, coastal erosion, and loss of wetlands. Conversion of the three canals used in this project will create approximately 15.5 acres and will enhance and protect an additional 30 acres.

Engineering Features:

Over 130,000 Christmas trees were collected from eight parishes. Jefferson Parish trees were collected by Browning-Ferris Industries at no cost to Jefferson Parish (county). These trees were delivered to an area located at 700 Peters Road, owned by the Louisiana Department of Transportation and Development. Twenty-thousand (20,000) trees were bundled by 500 volunteers

during January 1993. The remaining trees were bundled by parish employees during February, March, and April, 1993. All bundles were loaded onto nine barges and moved to the Goose Bayou area by two tugboats. First, the brush fences were filled by Jefferson Parish employees and then the rest of the trees were airlifted by the Louisiana Air National Guard on March 26 to 27, 1993. The steel bands were cut from the bundles by parish employees from April through June and collected for recycling. Fertilizing and monitoring of the canal test cells began in May 1993 and was continued through December 1994.

For this project, 2,600 feet of brusn fence was built. Each canal was divided into four cells in order to study which schedule of fertilizer application was most effective in accelerating marsh development. The following list summarizes the physical features that are in place:

- thirteen (13) brush fences

- eleven hundred (1,100) large tree bundles for airlift to fill the canals

- one thousand (1,000) small bundles for brush fences.

No other physical alterations to the site (e.g., dredging, filling, or diking) were done.

Monitoring Techniques:

Monitoring of the site is conducted twice per year, at the beginning and end of the growth season, for mat measurement and botanical survey. Because converting the canals into marshes is a long-term process, measuring mat thickness and depth measurement is a good indicator of success. Initial assessment of the project indicates success; for example, the floating marsh started developing in two of the cells in one of the canals by the end of the first year. More specific site studies are being conducted on fertilizing regimes and water quality monitoring.

Cost Analysis:

The total cost of the Barataria-Terrebonne Marsh restoration project is $176,203 (1992 dollars) (Table IV.22). Costs include the direct cost of converting three dead-end abandoned oil canals to marsh by using discarded Christmas trees, fertilization, monitoring, engineering and design. The actual cost of conversion was $120,729, or $40,243 per canal. These costs include donations of barges and a tugboat worth $40,000, airlift by the Louisiana Air National Guard (not calculated but involving two Huey helicopters and 15 men for 16 hours), labor of 500 volunteers ($15,000 or $5.00/hour for six hours), and meals for volunteers for five days ($5,000). The conversion materials costs ($16,059) were 13 brush fences at $8,761, or $674 each; 1,100 large tree bundles to fill the canals at $6,223, or $5.66 each; and 1,000 small bundles for the brush fences for $1,075, or $1.08 each. The monitoring costs were $2,074 in labor, $117 in supplies (chemical kits), and $3,900 for rental of an airboat. Fertilization costs consisted of $3,564 in labor, $654 in supplies (chemical kits),

$116 in equipment, and $2,600 for rental of an airboat. Engineering and design costs were $25,996 for design, $15,000 for a survey, and $1,453 for administration.

TABLE IV.22. Cost by Component, Barataria-Terrebonne NEP

| Project Component | Quantity | Unit | Equipment, Materials, Supplies, etc. | Labor | Total Costs ($1994) | Total Costs ($1992) |
|---|---|---|---|---|---|---|
| Convert oil canals to marsh | 3 | ea | $76,059 | $44,670 | $126,236 | $120,729 |
| Fertilizing | | LS | $3,370 | $3,564 | $7,250 | $6,934 |
| Monitoring | | LS | $4,017 | $2,074 | $6,369 | $6,091 |
| Engineering design | | LS | $42,449 | | $44,385 | $42,449 |
| **Total** | | | **$125,895** | **$50,308** | **$184,240** | **$176,204** |

Sources:

Project files and personal communication with Marnie Winter.

## Connecticut Department of Environmental Protection: Wetland Restoration, Connecticut

Point of Contact:

Mr. Tom Ouellette
Department of Environmental Protection
79 Elm Street
Hartford, CT 06106-5127
Phone: (203) 424-3034

Project Description, Location, and Goals/Objectives:

The Connecticut Department of Environmental Protection (DEP) Wetland Restoration Unit conducts a variety of restoration activities designed to restore or improve tidal exchange and native tidal wetland vegetation, such as replacement/enlargement of degraded culverts, removal of tidegates, excavation of marsh surface elevation, and reestablishment/creation of naturally configured wetland channels and pools. The projects are located in the state of Connecticut. There were approximately 63 projects in various stages of review or implementation under this program as of 1995. Four projects are reviewed here because of available detail on costs associated with engineering features.

Engineering Features:

There was very little information available for any of the projects. What was available is provided in the cost analysis below.

Monitoring Techniques:

None listed.

Cost Analysis:

Davis Pond. The total cost for the Davis Pond restoration project (covering 20 acres) is $22,290 (1994 dollars) (Table IV.22). Costs include the direct costs of channel and ditch cleaning, pond connection, design and monitoring. Labor costs for channel and ditch cleaning and pond connection were $1,225 per day for 13 days. Equipment costs include rental of a rotary ditcher at $135/day for eight days, rental of a SK60 excavator at $105/day for five days, and transportation at $200/day for four days. Planning, engineering, design, and monitoring (photography and salinity tests) labor is estimated at $285/day for three to ten days, and five days per six-month period, respectively.

Fort Saybrook. The total cost of the Fort Saybrook restoration project (covering 10 acres) is $34,640 (1994 dollars) (Table IV.22). Costs include removal of floatable debris (wood) from

channel, channel cleaning, installation of four open water management ponds, design, and monitoring. Labor costs for channel and ditch cleaning and pond connection are $1,225 per day for 21 days. Equipment costs include rental of a rotary ditcher at $135/day for eight days, rental of a SK60 excavator at $105/day for 13 days, rental of a John Deere bulldozer at $60/day for 8 days, and transportation at $200/day for ten days. Planning, engineering, design, and monitoring (photography and salinity tests) labor is estimated at $285/day for three to ten days, and five days per six-month period, respectively.

Village Creek. The total cost of the Village Creek restoration project (covering 20 acres) is $16,610 (1994 dollars) (Table IV.22). Costs consist of the cleaning of channels and installation of several open water management ponds, design, and monitoring. Labor costs for channel and ditch cleaning and pond connection are $1,225 per day for eight days. Equipment costs are rental of a rotary ditcher at $135/day for eight days, rental of a SK60 excavator at $105/day for four days, rental of a John Deere bulldozer at $60/day for three days, and transportation at $200/day for six days. Planning, engineering, design, and monitoring (photography and salinity tests) labor is estimated at $285/day for three to ten days, and five days per six-month period, respectively.

Manresa Island. The total cost of the Manresa Island restoration project (covering 25 acres) is $16,775 (1994 dollars) (Table IV.23). Costs consist of the cleaning of channels and installation of several open water management ponds, design, and monitoring. Labor costs for channel and ditch cleaning and pond connection are $1,225 per day for eight days. Equipment costs are rental of a rotary ditcher at $135/day for eight days, rental of a SK60 excavator at $105/day for five days, rental of a John Deere bulldozer at $60/day for three days, and transportation at $200/day for six days. Planning, engineering, design, and monitoring (photography and salinity tests) labor is estimated at $285/day for three to ten days, and five days per six-month period, respectively.

## TABLE IV.23. Cost by Component, Connecticut DEP Coves

| Project Component | Quantity | Unit | Equipment, Materials, Supplies, etc. | Labor | Total Costs ($1994) |
|---|---|---|---|---|---|
| Davis Pond | | | | | |
| Main channel, ditch cleaning, and pond connection | 20 | acres | $2,405 | $15,925 | $18,300 |
| Planning, engineering, and design | | | | $2,565 | $2,565 |
| Monitoring | | | — | $1,425 | $1,425 |
| Subtotal | | | $2,405 | $19,915 | **$22,290** |
| Fort Saybrook | | | | | |
| Floatable removal | | | $4,000 | $19,600 | $23,600 |
| Channel cleaned and ponds installed | 10 | acres | $925 | $6,125 | $7,050 |
| Planning, engineering, and design | | | | $2,565 | $2,565 |
| Monitoring | | | — | $1,425 | $1,425 |
| Subtotal | | | $4,925 | $29,715 | **$34,640** |
| Village Creek | | | | | |
| Channels cleaned and salt ponds installed | 20 | acres | $2,820 | $9,800 | $12,620 |
| Planning, engineering, and design | | | | $2,565 | $2,565 |
| Monitoring | | | — | $1,425 | $1,425 |
| Subtotal | | | $2,820 | $13,790 | **$16,610** |
| Manresa Island | | | | | |
| Channel cleaning and salt ponds installed | 25 | acres | $2,985 | $9,800 | $12,785 |
| Planning, engineering, and design | | | | $2,565 | $2,565 |
| Monitoring | | | — | $1,425 | $1,425 |
| Subtotal | | | $2,985 | $13,790 | **$16,775** |
| **Total** | | | | | **$90,315** |

Sources:

Project files and personal communication with Tom Ouellette.

## Des Plaines River Wetlands Demonstration Project, Illinois

Point of Contact:

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Wetlands Research, Inc.
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Phone: (312) 922-0777

Project Description and Location:

The project site is located 35 miles north of Chicago in Wadsworth, Illinois, and incorporates 2.8 miles of the Des Plaines River and 450 acres of riparian land within the Lake County Forest Preserve District. This is one of the largest, systematic research sites in the United States dedicated to demonstrating how wetlands can be restored to solve pressing environmental problems.

Project Goals/Objectives:

Since 1983, the Des Plaines River Wetlands Demonstration Project has pursued three goals: 1) restore and create riverine wetlands, prairie, and forest; 2) research the biological, chemical, and physical characteristics of wetlands in order to develop management guidelines for wetland restoration; and 3) educate the public, scientists, and policy makers about the functions and values of wetlands (Wetland Research, Inc. 1993). The Des Plaines River wetlands complex (450 acres) is divided into two parts: a passive experimental area devoted to restoring the landscape to emulate precolonial settlement conditions and an active experimental area dedicated to using created wetlands as research laboratories. In the passive experimental area, restoration work has included eliminating many Eurasian plant invaders, regrading the landscape, and reestablishing native plant communities through planting and controlled burning. The active experimental area presently contains six (ultimately eight), hydraulically-controlled experimental wetlands (EWs), designed to be easily and systematically changed. These wetlands are "living laboratories" for research into the physical, biological, and chemical processes of wetlands.

Engineering Features:

Construction began in spring 1986 and is ongoing. The following list summarizes the engineering features that are in place and the construction activities that were involved (Hey 1985a, 1985b):

- Quarry Lakes (South, Middle, North)--created submerged aquatic ledges, reduced slopes of the banks surrounding the lake, leveled and distributed spoil piles from the mining operation, built a submerged peninsula and island

- channel and dike--constructed between Quarry Lakes and the Des Plaines River

- Experimental Wetlands (EWs 1-6)--cleared unwanted vegetation, excavated/graded, constructed outlet control gates

- irrigation system--constructed intake structure and pump house, pumps, pipes and outfalls, valves, flow meters and water level recorders

- public use facilities--constructed parking lot, canoe launch, and fishing walls

- trails and bridges--built trails along both banks of the river, through and around the experimental wetlands.

<u>Monitoring Techniques</u>:

<u>Passive Experimental Wetland Area</u>. Monitoring of plants and animals has sdhown that wetland-dependent macrophytes and macroinvertebrates have increased and two state-designated endangered bird species (least bittern and yellow-headed blackbird) that were absent before restoration are now breeding on the site.

<u>Active Experimental Wetland Area.</u> The hydrologic monitoring system is designed and operated to facilitate the compilation of detailed water budgets incorporating water inflows (precipitation and pumped) and outflows (discharge, evapotranspiration, and seepage). The system consists of a climate station, groundwater monitoring wells, and surface water level recorders.

Turbidity and contaminants from agricultural and urban runoff are the primary water quality problems in the Des Plaines River. These experimental wetlands have been shown to remove pollutants from the river (more than 80 percent of the sediments and nutrients), store flood waters, and provide wildlife habitat. Since 1990, 14 research teams from 12 organizations have conducted studies in the four deep water marshes focused on the following: 1) how differing hydraulic loading rates affect water and sediment chemistry, sedimentation rates, plant community development, and primary productivity; and 2) how invertebrates, herpetofauna, birds, and mammals have responded to the restored habitats. Research to date suggests that to use constructed wetlands such as these to improve the water quality of an entire watershed would require converting only two to four percent of the land area to this use.

Research is being conducted in EWs 1 and 2 to investigate how wet meadows are established. Specific elements of this research are addressing two issues: 1) how to establish the necessary

hydrology and plant species while preventing the establishment of unwanted species; and 2) how quickly hydric soils form and what processes produce the indicators of hydric soil.

Between 1985 and 1992, more than 140 journal articles, book chapters, proceedings, graduate student theses, contract reports, newspaper articles, newsletters, and magazine articles have resulted from studies conducted at the site.

Cost Analysis:

The Des Plaines Wetlands Demonstration Project plan identifies eight wetlands areas with 99 acres to be cleared, three pond areas with a total of 70 acres to be cleared, and four river environs areas, with a total of 38 acres to be cleared. Grading, filling, drainage, temporary river crossings cost $1.7 million (1985 dollars) (Table IV.24). The project also included an irrigation system ($879,000) and public use facilities (fishing walls, canoe launch, trails, parking lot, and two bridges) at a cost of $573,000. Operating costs consist of pumping costs of $29,975 (24.1 cubic feet/second mean; 50 cubic feet/second maximum), pump maintenance for one year ($6,000), and labor (assigned to research program). Costs for grading and draining were estimated by McKie Consultants, Inc., for the irrigation system by Morris Environmental Engineering, Inc., and for public access facilities by Stephen F. Christy, landscape architect. The total cost of the project was estimated at $3.6 million in August 1985. The cost estimates were partly based upon a preliminary plan from 1983.

TABLE IV.24. Cost by Component, Des Plaines Experimental Wetlands

| Project Component | Quantity | Unit | Equipment, Materials, Supplies, etc. | Labor | Total Costs ($1994) | Total Costs ($1985) |
|---|---|---|---|---|---|---|
| Wetland areas 1.1-1.6 | | | | | | |
| Clearing | 71 | acre | | | $38,720 | $28,400 |
| Topsoil excavation | 21,600 | cy | | | $44,174 | $32,400 |
| Earth excavation | 210,500 | cy | | | $573,984 | $421,000 |
| Topsoil placement | 21,600 | cy | | | $51,536 | $37,800 |
| Subtotal, area 1 | | | | | $708,414 | $519,600 |
| Wetland Areas 2.1-2.2 | | | | | | |
| Clearing | 28 | acre | | | $15,270 | $11,200 |
| Topsoil excavation | 7,600 | cy | | | $15,543 | $11,400 |
| Earth excavation | 100,200 | cy | | | $273,222 | $200,400 |
| Topsoil placement | 5,300 | cy | | | $12,645 | $9,275 |
| Subtotal, Area 2 | | | | | $316,680 | $232,275 |

TABLE IV.24. (continued)

| Project Component | Quantity | Unit | Equipment, Materials, Supplies, etc. | Labor | Total Costs ($1994) | Total Costs ($1985) |
|---|---|---|---|---|---|---|
| North Pond area: | | | | | | |
| Clearing | 13 | acre | | | $17,724 | $13,000 |
| Topsoil excavation | 4,100 | cy | | | $8,385 | $6,150 |
| Earth excavation | 1,600 | cy | | | $4,363 | $3,200 |
| Channel excavation | 18,300 | cy | | | $63,375 | $45,750 |
| Topsoil placement | 4,100 | cy | | | $9,782 | $7,175 |
| Subtotal, North Pond | | | | | $103,629 | $75,275 |
| Middle Pond: | | | | | | |
| Clearing | 16 | acre | | | $21,814 | $16,000 |
| Topsoil excavation | 1,000 | cy | | | $2,045 | $1,500 |
| Topsoil placement | 3,300 | cy | | | $7,875 | $5,775 |
| Subtotal, Middle Pond | | | | | $31,734 | $23,275 |
| South pond: | | | | | | |
| Clearing | 41 | acre | | | $44,719 | $32,800 |
| Topsoil excavation | 16,400 | cy | | | $33,539 | $24,600 |
| Earth excavation | 29,600 | cy | | | $80,712 | $59,200 |
| Channel excavation | 23,000 | cy | | | $94,073 | $69,000 |
| Topsoil placement | 16,400 | cy | | | $39,129 | $28,700 |
| Subtotal, South Pond | | | | | $292,172 | $214,300 |
| River Environs Area 1: | | | | | | |
| Clearing | 9 | acre | | | $12,270 | $9,000 |
| Topsoil excavation | 4,000 | cy | | | $8,180 | $6,000 |
| Channel excavation | 32,000 | cy | | $2.50 | $109,071 | |
| Topsoil placement | 4,000 | cy | | | $9,544 | $7,000 |
| Subtotal, River Area 1 | | | | | $139,065 | $102,000 |
| River Environs Area 2: | | | | | | |
| Clearing | 7 | acre | | | $9,544 | $7,000 |
| Topsoil excavation | 3,900 | cy | | | $7,976 | $5,850 |
| Channel excavation | 25,300 | cy | | | $86,234 | $63,250 |
| Topsoil placement | 3,900 | cy | | | $9,305 | $6,825 |
| Subtotal, River Area 2 | | | | | $113,059 | $82,925 |
| River Environs Area 3: | | | | | | |
| Clearing | 13 | acre | | | $17,724 | $13,000 |
| Topsoil excavation | 14,100 | cy | | | $28,836 | $21,150 |
| Earth excavation | 62,600 | cy | | | $170,696 | $125,200 |
| Channel excavation | 10,700 | cy | | | $43,765 | $32,100 |
| Topsoil placement | 14,100 | cy | | | $33,641 | $24,675 |
| Subtotal, River Area 3 | | | | | $294,662 | $216,125 |

TABLE IV.24. (continued)

| Project Component | Quantity | Unit | Equipment, Materials, Supplies, etc. | Labor | Total Costs ($1994) | Total Costs ($1985) |
|---|---|---|---|---|---|---|
| River Environs Area 4: | | | | | | |
| Clearing | 9 | acre | | | $12,270 | $9,000 |
| Topsoil excavation | 10,200 | cy | | | $20,860 | $15,300 |
| Earth excavation | 33,900 | cy | | | $92,437 | $67,800 |
| Channel excavation | 9,400 | cy | | | $38,447 | $28,200 |
| Topsoil placement | 10,200 | cy | | | $24,336 | $17,850 |
| Subtotal, River Area 4 | | | | | $188,350 | $138,150 |
| Incidental Construction: | | | | | | |
| Outlet control structures | 8 | ea | | | $87,257 | $64,000 |
| 8-inch corrugated steel culvert | 130 | let | | | $3,190 | $2,340 |
| 24-inch corrugated steel culvert | 240 | let | | | $7,853 | $5,760 |
| 30-inch corrugated steel culvert | 30 | let | | | $1,350 | $990 |
| 36-inch corrugated steel culvert | 160 | let | | | $9,162 | $6,720 |
| 18-inch end section | 8 | ea | | | $1,091 | $800 |
| 24-inch end section | 2 | ea | | | $382 | $280 |
| 30-inch metal end section | 2 | ea | | | $682 | $500 |
| 24-inch flap gate | 6 | ea | | | $4,090 | $3,000 |
| Temporary river crossing | 3 | ea | | | $40,901 | $30,000 |
| Riprap | 1,050 | sy | | | $14,316 | $10,500 |
| Subtotal, construction | | | | | $170,274 | $124,890 |
| Irrigation System: | | | | | | |
| 12-inch DCIP irrigation line | 50 | lf | | | $1,363 | $1,000 |
| 16-inch DCIP irrigation line | 745 | lf | | | $25,393 | $18,625 |
| 18-inch RCP irrigation line | 155 | lf | | | $5,706 | $4,185 |
| 21-inch RCP irrigation line | 300 | lf | | | $11,861 | $8,700 |
| 24-inch RCP irrigation line | 1,540 | lf | | | $79,785 | $58,520 |
| 27-inch RCP irrigation line | 3,550 | lf | | | $193,600 | $142,000 |
| 30-inch RCP irrigation line | 873 | lf | | | $59,512 | $43,650 |
| 36-inch RCP irrigation line | 24 | lf | | | $1,800 | $1,320 |
| Twin box culvert (6-foot by 6-foot) | 84 | lf | | | $40,083 | $29,400 |
| Irrigation line river crossing | 350 | lf | | | $71,578 | $52,500 |
| Aggregate surface, Type B | 521 | tons | | | $7,103 | $5,210 |
| Seeding, Class II | 2.20 | acre | | | $4,499 | $3,300 |
| Pump manhole | 2 | ea | | | $8,180 | $6,000 |
| Channel excavation | 130 | cy | | | $532 | $390 |
| Stone riprap | 20.30 | sy | | | $277 | $203 |
| Clearing | 1.40 | acre | | | $1,909 | $1,400 |
| Valve vault, 4-foot diameter | 12 | ea | | | $8,180 | $6,000 |
| Valve vault, 5-inch diameter | 2 | ea | | | $1,636 | $1,200 |
| Trash rack | 2 | ea | | | $2,727 | $2,000 |
| Walkway for intake structure | 1 | LS | | | $3,408 | $2,500 |
| Outfall structure | 8 | ea | | | $6,544 | $4,800 |
| Check valve (30-inch diameter) | 2 | ea | | | $19,087 | $14,000 |
| Butterfly valve, 12-inch | 1 | ea | | | $954 | $700 |
| Butterfly valve, 16-inch | 5 | ea | | | $8,862 | $6,500 |

TABLE IV.24. (continued)

| Project Component | Quantity | Unit | Equipment, Materials, Supplies, etc. | Labor | Total Costs ($1994) | Total Costs ($1985) |
|---|---|---|---|---|---|---|
| Irrigation system (continued): | | | | | | |
| Butterfly valve, 20-inch | 1 | ea | | | $3,136 | $2,300 |
| Butterfly valuve, 24-inch | 1 | ea | | | $3,681 | $2,700 |
| Butterfly valve, 30-inch | 2 | ea | | | $10,907 | $8,000 |
| Combination air valve | 2 | ea | | | $2,727 | $2,000 |
| Flow meter, 12-inch | 1 | ea | | | $12,270 | $9,000 |
| Flow meter, 16-inch | 5 | ea | | | $68,169 | $50,000 |
| Flow meter, 20-inch | 1 | ea | | | $16,361 | $12,000 |
| Flow meter, 24-inch | 1 | ea | | | $17,724 | $13,000 |
| Flow meter, 27-inch | 1 | ea | | | $19,087 | $14,000 |
| Flow meter, 30-inch | 1 | ea | | | $20,451 | $15,000 |
| Valve boxes | 8 | ea | | | $1,091 | $800 |
| Blowoff valves | 2 | ea | | | $4,090 | $3,000 |
| Level probes | 9 | ea | | | $24,541 | $18,000 |
| Microchart recorder | 19 | ea | | | $33,676 | $24,700 |
| Pump and motor | 2 | ea | | | $109,071 | $80,000 |
| Variable speed drive | 1 | ea | | | $54,535 | $40,000 |
| Level controls | 8 | ea | | | $1,091 | $800 |
| Electrical work | 1 | LS | | | $231,775 | $170,000 |
| Subtotal, irrigation system | | | | | $1,198,962 | $879,403 |
| Public Access Facilities: | | | | | | |
| Parking lot | | | | | | |
| Topsoil | 8,600 | cy | | | $35,175 | $25,800 |
| Earthwork | 28,000 | cy | | | $85,893 | $63,000 |
| Seeding | 10 | acre | | | $5,454 | $4,000 |
| Class B pavement | 4,800 | sy | | | $52,354 | $38,400 |
| Class I pavement | 310 | sy | | | $3,593 | $2,635 |
| B.A.M. | 340 | sy | | | $5,113 | $3,750 |
| CA6, Grade 9 | 3,200 | tons | | | $43,628 | $32,000 |
| Concrete curb | 2,600 | lf | | | $18,133 | $13,300 |
| Concrete walks | 360 | lf | | | $3,190 | $2,340 |
| Bridges | 2 | ea | | | $2,045 | $1,500 |
| New trail-build | 12,650 | lf | | | $172,468 | $126,500 |
| Old trail-rebuild | 5,000 | lf | | | $13,634 | $10,000 |
| Trail bridges (2) | 200 | lf | | | $136,338 | $100,000 |
| Fishing walls 500 lf, and canoe launch 30 lf (gunite) | 1 | LS | | | $204,507 | $150,000 |
| Subtotal, Public Access | | | | | $781,525 | $573,225 |
| Planting costs | 237 | acre | | | $577,877 | $423,855 |
| **Total** | | | | | **$4,916,403** | **$3,605,298** |

Sources:

Wetlands Research, Inc. 1993. *"Living Laboratory" Offers Unique Research Opportunities to Improve Environmental Quality.* Wetlands Research, Inc., Chicago, Illinois. 10 pp.

Hey, D.L. 1985a. "Construction Plan." In *Design Construction Specifications and Site Management of the Des Plaines River Wetlands Demonstration Project*, D.L. Hey and N.S. Philippi, eds., Volume 3, Chapter 7. Wetlands Research, Inc., Chicago, Illinois. 4 pp.

Hey, D.L. 1985b. "Costs." In *Design Construction Specifications and Site Management of the Des Plaines River Wetlands Demonstration Project*, D.L. Hey and N.S. Philippi, eds., Volume 3, Chapter 8. Wetlands Research, Inc., Chicago, Illinois. 16 pp.

**Metzger Marsh, Ohio**

Point of Contact:

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Project Description and Location:

The State of Ohio has lost 90 percent of its original wetlands, and coastal marshes of Lake Erie have suffered the greatest losses (USFWS 1993). Metzger Marsh, a 900-acre coastal marsh along the shores of western Lake Erie is under joint management by Ottawa National Wildlife Refuge (ONWR) and Ohio Division of Wildlife (ODW). The marsh is one of the last remaining undiked coastal wetlands in the southwestern part of Lake Erie. Wetland vegetation in the marsh has been severely damaged by wave action following erosion of the barrier beach that once protected the wetland. The eroded barrier beach can no longer be sustained due to insufficient sediment supply.

Proposed restoration of Metzger Marsh to a multifunctional, lacustrine, emergent coastal wetland will entail constructing a dike to replace the barrier beach and an innovative water/fish control structure that mimics the function of a natural connection between the wetland and the lake; this structure will allow reestablishment of emergent wetland vegetation, enable initial drawdowns to be conducted, and will also allow managers to restrict movement of large carp into the wetland while selectively allowing other fish to pass through the structure (Wilcox 1994a).

Project Goals/Objectives:

The project will demonstrate practices for restoring and protecting coastal wetland habitat through revegetation, while concurrently restoring natural hydrologic functions and increasing habitat for species such as Great Lakes muskellunge, northern pike, and black duck. This project is a joint venture under the North American Waterfowl Management Plan involving funds from the USFWS, ODW, and nine private organizations. The new restoration and management techniques associated with this project have the potential for redirecting marsh management decisions in all of the Great Lakes. If this project proves successful, ODW personnel have indicated that there are at least 20 other diked wetlands along the Lake Erie shore to which the Metzger Marsh restoration methods could be applied.

Expected results of the overall project are an increase in vegetated habitat for many species of fish, birds, and other wildlife, reestablishment of the water quality and hydrologic functions of the wetland, and development of methods for holistic management of diked wetlands.

Engineering Features:

Initial dike construction began on September 26, 1994, and all construction is expected to be completed by September 31, 1996. Borrow for the 7,700-linear-foot lakefront dike across the face of the marsh is planned as a 60-acre manageable wetland landward of Metzger Marsh. The five-bay fish access/water control structure is designed to allow manageable hydrologic marsh/lake interchange, and to limit access of large carp into the wetland. Water flow through the structure will be limited by the size of the gates to prevent flooding or dewatering during extreme seiche events (occasional and sudden oscillations of a body of water, causing fluctuations in the water level, and brought about by wind, earthquakes, changes in barometric pressure, or other factors). Lesser seiche events will drive routine water flows across the structure. A water maintenance pump structure will also be installed to augment dewatering and reflooding (USFWS 1993).

Monitoring Techniques:

Multidisciplinary research will guide and track restoration efforts (Wilcox 1994a). As proposed presently, monitoring will include the following studies by fiscal year:

FY95: Prior to completion of dike construction and implementation of the control structures, fish, small mammals, herpetofauna, macroinvertebrates, plankton, waterfowl, and plant communities will be sampled according to a stratified random design using standard techniques. Existing plant communities will be mapped from aerial photographs, with groundtruthing, according to major vegetation types. Historic plant communities will be mapped from aerial photographs by photointerpretation. Geologic studies will be conducted using a vibra-corer and other methods. Studies will also be completed on the effectiveness of stocking high densities of predator fish as a means of controlling undesirable carp populations. In addition, plant macrofossil analyses will be conducted on peat cores collected from the wetland to characterize presettlement wetland plant communities and guide any seed-bank augmentation.

FY96, FY97: During the planned drawdown of Metzger Marsh to reestablish emergent plant communities, GIS mapping, vegetation, shorebird, small mammal, herpetofauna, fish, macroinvertebrate, plankton, waterfowl, and water quality studies will be conducted at undiked control sites. The drawdown will be for a two-year period (summer 1996 to summer 1998) to mimic low lake level. Following the drawdown, the wetland level will be raised to the natural lake level.

FY98, FY99, FY00: Following reestablishment of hydrologic connection with the lake, all FY95 studies will be repeated in Metzger Marsh.

Cost Analysis:

The total construction cost of the Metzger Marsh Project is expected to be about $5.3 million (1994 dollars) (Table IV.25). The project includes a 7,700-foot dike completed at a cost of $3.6 million ($1.07 million in labor), or about $465 per linear foot. Also included in the plan is a water control structure and pump house. Combined, these facilities are expected to cost $1.7 million ($775,000 in labor). Engineering and design, included in the totals above, was a reported $400,000. Of this, $300,000 was donated by outside organizations. Annual maintenance costs were conservatively estimated at $10,000 per year, while annual monitoring costs varied from as low as $104,000 expected in 1996 to as high as $190,000 expected in 1999. The average annual monitoring cost during the period 1994 to 2000 is $149,800. This yields an expected annual operating cost of around $160,000.

TABLE IV.25. Cost by Component, Metzger Marsh

| Project Component | Quantity | Unit | Equipment, Materials, Supplies, etc. | Labor | Total Costs ($1994) |
|---|---|---|---|---|---|
| Dike Construction: | 7700 | lf | | | |
| Surveying | | LS | | $26,000 | $26,000 |
| Site Preparation | | LS | | $15,100 | $15,100 |
| Earth Fill | | LS | | $184,900 | $184,900 |
| Geotextile Placement | | LS | | $8,000 | $8,000 |
| Filter and Stone Placement | | LS | | $8,200 | $8,200 |
| Rock on Inside of Dike | | LS | | $8,200 | $8,200 |
| Riprap on Outside of Dike | | LS | | $16,400 | $16,400 |
| Other--Materials, Equipment, Supplies, Profit | | | $3,828,500 | $0 | $0 |
| Subtotal, Estimated | 7700 | lf | $3,828,500 | $266,800 | $4,950,300 |
| Subtotal, Actual Bid | 7700 | lf | $2,504,780 | $1,073,478 | $3,578,258 |
| Labor estimated at 40% bid less profit | | | | | |
| Fish Access and Water Control | 1 | ea | $482,485 | $282,485 | $764,970 |
| Pump Structure | 1 | ea | $321,906 | $200,344 | $555,250 |
| Electric Line | 1 | LS | $12,000 | | $12,000 |
| Subtotal, Initial estimate for both fish access structure and pump house | 1 | LS | $816,391 | $482,829 | $1,299,220 |
| Subtotal, Updated estimate for both fish access structure and pump house | 1 | LS | $947,650 | $775,350 | $1,723,000 |
| Labor estimated at 60% total less profit | | | | | |
| Total, Initial estimate | | | $4,644,891 | $749,629 | $5,394,520 |
| Total, Updated estimate | | | $3,452,430 | $1,848,828 | **$5,301,258** |
| Annual Operating Costs: | | | | | |
| Monitoring (average, 1994-2000) | 1 | LS | $0 | $149,800 | $149,800 |
| Maintenance (estimate) | 1 | LS | $0 | $10,000 | $10,000 |
| **Total Annual Operating Cost** | | | **$0** | **$159,800** | **$159,800** |

Sources:

USFWS (U.S. Fish and Wildlife Service). 1993. *Metzger Marsh Coastal Wetland Restoration Project, Lucas County, Ohio. Environmental Assessment and Finding of No Significant Impact.* U.S. Fish and Wildlife Service, Great Lakes-Big Rivers Region, Twin Cities, Minnesota.

Wilcox, D. 1994a. *Development of Methods and Strategies for Restoration and Management of Diked Wetlands for Water Quality, Fish, and Wildlife.* Draft proposal to U.S. Environmental Protection Agency, Washington, D.C.

Wilcox, D. 1994b. *Information Transfer Guides Restoration of Metzger Marsh in Lake Erie.* Proceedings of the 1994 Society of Wetland Scientists Annual Meeting, Portland, Oregon.

## Natural Resources Conservation Service (NRCS) Wetland Reserve Program in Washington State

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Project Description, Location, and Goals/Objectives:

Vast amounts of agriculture land in the United States have been developed on former wetlands. Modification of hydrology and years of food production and grazing has resulted in a complete loss of any wetland features on this land. The 1990 Food and Agriculture Conservation and Trade Act (Farm Bill) authorized $60 million for purchase of agricultural land from private land owners in order to restore wetland features and preserve this land in perpetuity as wetlands. Lands are sought within which wetland functions can be restored with relatively little physical actions. The intent is to return former wetlands to full functional performance at a minimal cost (other than the price of the land). Under the program, the land owners voluntarily apply to have their property purchased. Twenty states participated in the program in 1994. In Washington, two primary project areas totalling 600 acres were purchased. Three adjacent parcels of property were purchased in Snohomish County that amounted to 400 acres. The remaining 200 acres are located in Spokane County.

The Natural Resources Conservation Service and the WDFW have cooperated in this project. In general, these agencies work together to assure that the proper actions are taken to restore and monitor the wetlands.

Engineering Features:

Snohomish County. The primary methods for restoring wetland features to the Snohomish County parcels involved restoring hydrology, planting trees, and seeding the property. Drainage tiles that were originally installed to shunt water away from the property are being removed. The entire 400 acres were seeded with clover to restore soil conditions. Trees (primarily willow, red osier dogwood, water birch, black cottonwood) were planted on 500-foot centers throughout the property. In addition, a total of 78 clumps of wetland shrubs was planted. The very sparse plantings are meant to provide seed sources for natural colonization of the remainder of the property rather than to provide habitat for wildlife.

Spokane County. The project in Spokane County involves approximately 209 acres near Newman Lake and is presently pending the final filing of the easement agreement. The plan for restoration involves a cessation of cropping and planting of trees as was done in the Snohomish County project. According to the "Conservation Plan Schedule of Operation," the primary emphasis of the permanent easement is the restoration and protection of wetlands for wildlife habitat, water quality improvement, flood control, and as a recharge area for the local water table. Additional functions from the restoration include recreational, educational, and research opportunities. The easement area is expected to add value to the existing wetland-open water complex of Newman Lake. No major hydrological modifications are planned since it is believed that natural hydrology will be restored upon cessation of cropping activities.

Monitoring Techniques:

The WDFW is responsible for monitoring the Snohomish system. It will record general changes in the vegetation through annual visits to the property. It will also record observations on hydrology and wildlife. Photographs will be taken to document the changes at selected points throughout the property. Quantitative monitoring will involve counting the number of surviving trees and shrub clumps. There are no monitoring plans in place for the Spokane County project as yet.

Cost Analysis:

This project involves the purchase of farmland, removal of drain tiles, and replanting of acreage with selected woody species to reestablish wetlands ground cover. The total cost of the project is $642,200 (1994 dollars) for 400 acres or $1,605 per acre. Most of the costs are for land acquisition at $1,500 per acre ($600,000 total). Of the remainder, $35,000 was for tile breaks, $3,000 for planting trees, $1,950 for planting shrubs, and $1,500 for disposal of tiles. No estimate was given for engineering design and planning costs or for maintenance and monitoring.

Sources:

The purchase agreements that identify the purpose and function, compatible uses, and other aspects of the action are available (please contact NRCS).

## Shaker Trace Wetland Complex, Ohio

Point of Contact:

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Project Description and Location:

The Shaker Trace Wetland Complex is located in southwestern Ohio at Miami Whitewater Forest, the largest regional park in Ohio. The Hamilton County Park District is in the process of restoring a 40-hectare wetland on original hydric soils, which were identified on 200-year-old land survey records and soil maps. This restoration effort involves constructing low level dikes, excavating shallow depressions, and removing drain tile. One half of the 8 hectares restored in 1991 was planted with native wetland plant seeds collected within 100 miles of the Cincinnati area and nursery-grown plants propagated from these seeds. Several native amphibian larvae were also introduced at the site. The other half of the area was left unplanted to be revegetated by natural vectors and propagules from the seed bank.

Project Goals/Objectives:

The goal is to restore a functioning wetland system on original hydric soils to provide habitat for a wide diversity of wetland plant species and to attract a variety of wildlife species, all of which depend on wetlands for survival.

Engineering Features:

Project construction began in July 1991. The project is now in the fourth and final phase. The following physical structures have been built: six dams, six outflow structures with gate valves, four compacted-clay dikes (1-meter [3.28 feet]-high by 30- to 60-meters [98.4- to 196.8-feet]-long), a 3.6-meter (11.8-feet)-deep clay barrier (to prevent water from draining under the dikes), and 35 potholes. In addition, all 20-centimeter (7.9-inch) clay drain tile within a 30-meter (98.4-feet) radius of each structure was removed. Contouring was done to ensure that no area in the wetland complex exceeded a 10 percent grade.

Monitoring Techniques:

Vegetation was monitored during 1992-1993 to determine the success and benefit of the 1991 planting effort (Conover and Klein 1994). Some of the planted species that have become successfully established include water plantain, swamp milkweed, fen aster, nodding beggar-tick, wild cenna, common buttonbush, great blue lobelia, bushy seedbox, monkey flowers, swamp lousewort, false dragon-head, prairie cordgrass, and blue vervain. In addition, many unplanted species have also become established; selected species include sedges, conobea, umbrella sedges, spike rushes, boneset, clammy hedge-hysop, St. Johnswort, rushes, false pimpernel, marsh seedbox, ditch stonecrop, stalking yellow cress, broad-leaf arrow-head, water pimpernel, bulrush, and common cocklebur. The seeds of many of these unplanted species must have lain dormant in the soil for at least several decades prior to the restoration effort. Although many desirable species naturally colonized the unplanted area, the planting effort enriched the overall biodiversity of the wetland. A seed nursery has been established to supply seeds for future restoration efforts at this site or others.

In addition to vegetation surveys, the Park District has been conducting weekly monitoring of abundances of amphibians, reptiles, birds, and aquatic insects. These data are not yet available for public release. However, the area has attracted wetland wildlife including sandhill cranes, water pipits, common snipe, northern spring peepers, and blue-winged teals.

Cost Analysis:

The Shaker Trace project cost a total of $59,500 (1994 dollars) for four phases constructed between July 1991 and October 1994 (Table IV.26). Some cost details are available for the individual components of the project, but the breakdown between labor and materials is not. Planning the complex cost approximately $1,800 (including staff labor); construction of six dams and four dikes cost about $40,000; tile removal cost $700; contouring 35 potholes/ponds cost $15,000; and seed planting activities cost $2,000 (Hamilton County had established its own nursery to produce the seeds). Monitoring activities include an annual plant survey costing $2,000, and maintenance consists of annual burning or mowing at a cost of $1,000.

TABLE IV.26. Cost by Component, Shaker Trace Wetland Complex

| Project Component | Quantity | Unit | Equipment, Materials, Supplies, etc. | Labor | Total Costs ($1994) |
|---|---|---|---|---|---|
| Planning | 1 | LS | | | $1,800 |
| Construction of dams and dikes | 10 | ea | | | $40,000 |
| Tile removal | 1 | LS | | | $700 |
| Pond contouring | 35 | ea | | | $15,000 |
| Seed planting | 20 | ha | | | $2,000 |
| **Total Construction** | | | | | **$59,500** |
| Monitoring | 1 | LS/year | | | $2,000 |
| Annual burning and mowing | 1 | LS/year | | | $1,000 |
| **Total Monitoring and Maintenance** | | | | | **$3,000** |

Sources:

Klein, J. 1992. "Drain-Tile Removal, Recontouring, Planting Characterize Wetland Restoration Project (Ohio)." *Restoration and Management Notes* 10(2): 186-187.

Conover, D.G., and J. Klein. 1994. "Both Planted and Non-Planted Species Populate Restored Wetland (Ohio)." *Restoration and Management Notes* 12(2): 195-196.

## Rincon Bayou--Nueces Marsh Wetlands Restoration and Enhancement Project, Texas

Point of Contact:

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Austin, TX 78701
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Project Description and Location:

The Bureau of Reclamation's Rincon Bayou--Nueces Marsh Wetlands Restoration & Enhancement Project (Rincon Bayou Project) is a four-year demonstration project intended to restore and enhance coastal wetlands. The project is located within the Nueces River delta, just northwest of the city of Corpus Christi, Texas. Congress authorized this project to demonstrate the benefits of introducing freshwater into a coastal estuary by means of a wetland marsh system. This project will allow a more frequent inundation of the delta marsh from flood flows in the Nueces River for the purpose of measuring the resulting productivity. If the project demonstrates that rerouting of freshwater through this wetland system is more beneficial to the receiving bay and estuary, a preliminary management plan to establish and maintain these wetland areas will be developed (U.S. Department of Interior 1993).

Project Goals/Objectives:

The goal of the Rincon Bayou Project is to design and maintain a system that facilitates a greater frequency of deltaic inundation events from flood flows in the Nueces River. This includes a few non-permanent modifications that will allow flood flows (and possibly reservoir releases) to reach the upper Nueces Bay by way of the natural wetland and marsh system. At present, there is no intention to divert any part of the normal river flow of the Nueces, nor to provide a continuous, uninterrupted source of freshwater to the delta (U.S. Department of Interior 1993).

Engineering Features:

All of the planning for the Rincon Bayou Project has been completed and the monitoring program has been initiated. At the time of this summary, permitting and easements were in the process of being acquired and construction was scheduled to begin in January 1995. The physical structures are intended to divert and distribute freshwater in the study area, thereby providing a greater opportunity for freshwater inundation in the Nueces delta marsh. The following list summarizes the physical modifications planned prior to the excavation of approximately 200 feet of the Nueces River's north bank (U.S. Department of Interior 1993):

- Nueces River Overflow Channel--Approximately 898 feet of the river overflow channel, which is 1000 feet long, will be initially excavated. This feature, after excavation of the remaining 200 feet of river bank, will partially redirect elevated river flows above two feet mean sea level (MSL) into the delta, increasing the frequency and magnitude of flooding events.

- Rincon Bayou Overflow Channel--Approximately 2,000 feet of channel between the existing Rincon Bayou and the low area in the northern part of the delta will be excavated. The purpose of this channel is to supply the extensive mudflats and sparsely vegetated areas with freshwater by allowing flood flows in the Rincon channel to flush the northern areas of the delta. This channel will also prevent backwaters in these areas from remaining excessively saline and stagnant.

- Rincon Bayou Dike--Located approximately 0.25 miles upstream of the railroad bridge crossing, this 600-foot dike will be constructed across the Rincon channel. The purpose of this structure is to maximize the benefit of redirected flood flows by increasing their retaining time in the upper reaches of the delta. The dike will act as a salt water barrier to prevent saline intrusion into the upper study area and will also serve as the primary outflow measurement structure when used in conjunction with water level measurements.

- Low Water Crossing and Access Roads--The construction (or upgrading) of low water crossings and access roads will provide access to the downstream areas during all but highest flooding conditions. This will facilitate construction, maintenance, and monitoring activities, as well as rancher access during the demonstration period.

Once the above construction has been completed, the remaining 200 feet of the existing Nueces River embankment will be excavated to elevation two feet MSL. This action is reserved as the last to reduce potential interruptions smaller floods could have on the construction work.

Monitoring Techniques:

The monitoring plan is intended to be a flexible document that the Bureau of Reclamation can modify, as necessary, to accomplish the study objectives (U.S. Department of Interior 1993). The plan has been designed to provide scientifically valid data collection based on input from technical experts considering time and budget constraints. Reclamation's contribution to ongoing assessments will be directed toward measuring effects of freshwater inundation on productivity in the upper delta region. These data will be combined with data collected by other groups in the lower delta region and will be used to evaluate changes in productivity within the bay-estuary system. Sample sites will be selected targeting two separate regions ("treated" and "untreated") in the upper delta marsh area using a stratified, random approach. Parameters that the plan addresses may be divided into four groups: environmental contaminants, biological, water chemistry, and hydrological (U.S.

Department of Interior 1993). The exact number of sampling stations and their exact locations will be determined by the monitoring team after field investigations.

The biological monitoring program of the Bureau of Reclamation's Rincon Bayou Project measures three major elements: 1) primary productivity, 2) macrophytes, and 3) infaunal populations (Appendix "A" of the Assistance Agreement between the Texas Water Development Board and the Bureau of Reclamation). The monitoring plan contains a description of the different variables under each element that are to be measured, the desired field schedule for actual data collection, methodology to be employed during data collection or analysis, and a description of the desired form and schedule for end product delivery. The specific location of each monitoring state shall be mutually determined by the Texas Water Development Board and the Bureau of Reclamation before the monitoring period begins and then recorded with all subsequent data collection. The designated number of monitoring stations for each major element is as follows: primary productivity (6), macrophytes (5), and infaunal populations (5). Reports will consist of data analysis and interpretation, including figures, tables, and text, as needed, to adequately describe changes in macro- and meiofaunal populations.

The Bureau of Reclamation requested that the Corpus Christi Field Office of the USFWS conduct a baseline survey of contaminants in biota and sediments from Rincon Bayou prior to construction of the project. Field work began in August 1993 and was completed in September 1993. Ten sediment and 10 biota samples (fish) were collected and submitted to the analytical laboratory for a complete contaminants analysis, including polynuclear aromatic hydrocarbons (PAHs), aliphatics, organochlorines, and preconcentrate ICP-scan with enhanced mercury, selenium, and arsenic. An interim report is being prepared. Once the project is completed, additional samples could be collected.

Mapping of the Rincon Bayou-Nueces Bay estuary vegetation cover was initiated by the Bureau of Reclamation's Austin, Texas, office in support of the Rincon Bayou Project (Salas 1994). The data for the development of the Rincon Bayou wetlands mapping were compiled from a variety of different sources and then were entered into a Geographic Information System database for inventory and analysis. One plot of the Rincon Bayou estuary and adjacent lands has been produced. The plot shows the distribution of eight vegetation classes, two mud flat classes, open water, and residential and industrial locations. The base map includes ancillary information such as the location of roads and railroads, and a universal transfers mercater (UTM) grid.

<u>Cost Analysis</u>:

This project, as finally implemented, involves the excavation of two overflow channels and numerous access road improvements in the Rincon Bayou/Nueces marsh area. A dike originally included in the plan for the project was eliminated because some of the land owners raised road beds in the area. Besides improving the roads, the road beds had the additional virtue of retarding water outflows, thereby performing the function the dike was to have performed. This reduced construction

costs from the original estimate of $600,000 to under $300,000 (1994 dollars) (Table IV.27). The Rincon Bayou Overflow Channel, 2,000 feet long, was constructed for an easement cost paid to the landowner of $165,000, or about $82.50 per linear foot of channel. The cost also included the easement, stockpiling the earth removed from the channel along the channel, and numerous access road improvements (including 13, 48-inch-diameter culverts). The second phase is the Nueces River Overflow Channel, 898 feet in length and yet to be contracted. It is estimated to cost another $60,000 to $70,000 when completed (almost $78 per linear foot). Engineering design for the project cost just over $42,000. Operating costs are expected to total about $126,000 per year, including a monitoring program at $94,000 and management costs of $30,000. There is expected to be no maintenance cost associated with the project.

TABLE IV.27. Cost by Component, Rincon Bayou-Nueces Marsh Wetland Enhancement and Restoration Project

| Project Component | Quantity | Unit | Equipment, Materials, Supplies, etc. | Labor | Total Cost ($1994) |
|---|---|---|---|---|---|
| Construction: | | | | | |
| Excavate 2,000 feet of channel in Rincon Bayou, reconstruct low water crossings and access, including easements, 13, 48-inch culverts. | 1998 | lf | | | $166,000 |
| Excavate Nueces Overflow Channel | 898 | LS | | | $70,000 |
| Engineering design | 1 | LS | | | $42,172 |
| Nueces Estuary Regional Wastewater Planning Study, Phase I | 1 | LS | | | $150,166 |
| Nueces Estuary Regional Wastewater Planning Study, Phase II | 1 | LS | | | $258,000 |
| Nueces County Regional Stormwater Management Study | 1 | LS | | | $280,258 |
| Monitoring by Conrad Blucher Inst. | 1 | LS | | | $70,000 |
| Other Monitoring | 1 | LS | | | $54,900 |
| **Total Construction** | | | | | **$1,091,496** |
| Operations: | | | | | |
| Out-year Operations Management through September 1998 | 1 | year | annual cost | | $30,000 |
| Monitoring Costs | | | | | |
| Primary productivity | 6 | Sites | annual cost | | $40,600 |
| Macrophytes | 5 | Sites | annual cost | | $21,000 |
| Infaunal population dynamics | 5 | Sites | annual cost | | $33,000 |
| **Total Operations** | | | | | **$124,600** |

Sources:

Texas Water Development Board and the Bureau of Reclamation. Unpublished. Appendix A of Assistance Agreement between the Texas Water Development Board and the Bureau of Reclamation for the biological monitoring program of Reclamation's Rincon Bayou-Nueces Marsh Wetlands Restoration & Enhancement Project, Texas. 5 pp.

Salas, D.E. 1994. Vegetation Assemblage Mapping of the Nueces River Delta, Texas (Remote Sensing). Applied Sciences Referral Memorandum No. 94-4-2. Memorandum to Head, Remote Sensing and Geographic Information Section, Attention: D-3744.

U.S. Department of Interior. 1993. Plan of Study: Rincon Bayou-Nueces Marsh Wetlands Restoration & Enhancement Project. Bureau of Reclamation, Great Plains Region, Austin Reclamation Office, General Investigations Study. November 1993. 56 pp.

## PROJECTS IN CANADA

Below are two examples of projects in Canada having high quality goals, engineering features, and costing.

### Campbell River Estuary Enhancement, British Columbia

Point of Contact:

Dr. Colin Levings
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Canada V7V 1W6
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Project Description and Location:

The Campbell River estuary is located immediately north of the Municipal District of Campbell River on the east coast of Vancouver Island. Prior to 1982, log-handling practices in the Campbell River estuary impaired the estuary's utility as salmon habitat. On-water log sorting, booming, and storage were reduced significantly following the construction of a dry-land log facility in July 1982 (Hagen 1987). Approximately 37 acres of tidal areas were dredged or filled to produce the new facility.

Project Goals/Objectives:

In conjunction with construction of this facility, the central portion of the estuary was used for construction of artificial islands and building of manmade marshes to enhance wild salmon productivity. The reduction of log storage on lot 1486 was from 81 acres to 16.8 acres, a decrease of 64.2 acres. Log debris and bark were also cleared from 56.8 acres of mudflat surrounding the new islands. It was expected that by the time the constructed islands were fully colonized by plants, that the new marsh area would be up to 15 times that lost to the dry land sorting facility. Enhancement of the Campbell River estuary for salmonid resources was the first large-scale project in British Columbia to investigate marshland rehabilitation, and one of the few anywhere involving construction of artificial islands.

Engineering Features:

The one supratidal and four intertidal islands constructed on the old lot 1486 totaled 7.9 acres of flat surface and side slope area. The islands were constructed with inlets of various orientations--upstream, downstream, on front or back sides--to examine wild salmon habitat preferences. Approximately 4.2 acres of the new islands were planted with various spacings of marsh core plugs of different sizes and species composition. Donor sites for the marsh core plugs were remnant marshes that were to be dredged and filled for the dry land sorting facility.

Monitoring Techniques:

No formal performance criteria were set for this project. Baseline studies were performed to determine a design for the islands prior to construction. After construction, water was released from a reservoir upstream from the site, in order to simulate high-river discharges at low tide and to evaluate island stability. Monitoring of vegetation growth, colonization, and productivity was also undertaken. A variety of sampling programs were initiated to study the use of Campbell River estuarine habitats by wild juvenile salmonids. These programs included beach seine sampling, analysis of salmonid catch data from Campbell River and Discovery Passage, and recovery of coded wire tag data. Due to their importance in the estuarine food chain, sampling of zooplankton and meiofauna was also undertaken.

Of the 29 plant species present in the transplanted sites, plant communities were dominated by two species, arctic rush and Lyngby's sedge, which were considered the most important in terms of invertebrate use and of salmonid food-chain dynamics. By 1985, the new Campbell River estuarine marshes contained 60 percent of the biomass in natural marshes. Fewer invertebrates were evident in the new marshes as compared to established marshes, and detritus levels were also lower in the new marshes. Juvenile salmon use of the new island habitats was variable from year to year, but the overall productive capacity of the estuary appeared to increase. Several factors confounded assessment of the productive capacity of the new habitats for wild juvenile salmon: 1) difficulties with using adult salmon return numbers as an indication of productive capacity, 2) difficulties in quantifying whether increased productivity was a function of gains in marsh area, 3) the presence of hatchery-bred fish from the Quinsam River hatchery, and 4) the lack of adequate baseline data. It was felt that simply removing on-water log handling activities from the estuary to dry-land probably enhanced salmon productivity (Hagen 1987).

Cost Analysis:

British Columbia Forest Products moved from water sorting of logs to a dry land sorting operation in the Campbell River estuary. Besides improving water quality, the move increased sorting capacity from 295,100 cubic yards/year to 520,000 cubic yards/year. Total costs of the project were $4.5 million (Canadian), mainly expended between November 1981 and March 1982 (Table IV.28). Out of the $4.5 million, about $162,300 was expended for "estuarine rehabilitation" and "old dump

cleanup." Dump cleanup activities included cutting out old pilings and removing wood waste. Islands were created at low tide in the old log handling area. These were then planted with plugs of marsh vegetation that had been cut in sizes of approximately 4 to 10 inches in thickness. Detailed cost data are not available, but most of the costs of rehabilitation involved the planting activity.

TABLE IV.28. Cost by Component, Campbell River Dry Land Sort Facility (Canadian dollars)

| Project Component | Quantity | Unit | Equipment, Materials, Supplies, etc. | Labor | Total Costs ($1982) |
|---|---|---|---|---|---|
| Site preparation | | LS | $361,611 | | $361,611 |
| River diversion pipe | | LS | $55,654 | | $55,654 |
| Dredging | | LS | $1,673,744 | | $1,673,744 |
| Drainage system | | LS | $71,976 | | $71,976 |
| Boom ground construction | | LS | $357,878 | | $357,878 |
| Ribbing grid | | LS | $27,727 | | $27,727 |
| Riprap | | LS | $303,684 | | $303,684 |
| Layout and consulting | | LS | $151,311 | | $151,311 |
| Paving | | LS | $388,473 | | $388,473 |
| Barge grid | | LS | $63,772 | | $63,772 |
| Subtotal | | | $3,455,830 | | $3,455,830 |
| Equipment | | LS | $968,269 | | $968,269 |
| Subtotal | | | $968,269 | | $968,269 |
| Estuary rehabilitation | | LS | $143,640 | | $143,640 |
| Old dump cleanup | | LS | $18,626 | | $18,626 |
| Subtotal | | | $162,266 | | $162,266 |
| **Total** | | | **$4,586,365** | | **$4,586,365** |

Sources:

Brownlee, M.J., E.R. Mattice, and C.D. Levings. 1984. *The Campbell River Estuary: A Report on the Design, Construction, and Preliminary Follow-up Study Findings of Intertidal Marsh Islets Created for Purposes of Estuarine Rehabilitation.* Canadian Manuscript Report of Fisheries and Aquatic Sciences No. 1789, Canada. 53 pp.

Hagen, M.E. 1987. *Log-handling Impacts on Estuarine Environments: An Analysis of the Campbell River Estuary, British Columbia.* M.S. Thesis. Simon Fraser University, Vancouver, British Columbia.

## North Fraser Harbour Habitat Compensation Bank, Vancouver, British Columbia

Point of Contact:

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Coquitlam, British Columbia
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Project Description and Location:

The North Fraser Harbour compensation bank was established in Vancouver, British Columbia, to create sedge intertidal marsh for habitat banking purposes. The concept of habitat banking was considered beneficial because viable habitat for compensation is created in advance of a development proposal. In addition, banking has been shown to result in creation of larger habitat areas as opposed to several smaller projects, which were typically more expensive per unit area and provided fewer ecological benefits. Approximately 6,578 square yards of marsh credits were created adjacent to Gladstone Park and the Kerr Street Pier. The habitat compensation bank was a component of a larger City of Vancouver project to redevelop former industrial waterfront lands into the Fraser Lands Riverfront Park. Project costs for the habitat bank were borne by the North Fraser Habour Commission (NFHC), with some contributory funds from the Vancouver Board of Parks and Recreation.

Project Goals/Objectives:

The overall goals of the project were to construct stable and viable marsh habitat to be used for habitat compensation for future development proposals, and to establish a park design that was acceptable to adjacent residents, funding agencies, and environmental agencies. One specific goal was to modify the existing shoreline to reduce the linear nature of the bank. The alternative that best met this goal was creation of intertidal marsh, preservation of existing riparian vegetation (mature black cottonwood trees), and creation of riparian benches for shrubs.

The following criteria were used for selecting habitat banking sites within the North Fraser Harbour: 1) locations where habitat was most needed; 2) availability of sites for habitat enhancement; 3) sites where habitat could be created from upland, rather than from filling intertidal areas; 4) feasibility and cost; 5) possibility of achieving multiple uses; 6) compatibility with existing uses and designations; and 7) land ownership. The habitat banking initiative was a cooperative venture between the NFHC and Department of Fisheries and Oceans (DFO), as part of the North Fraser Harbour Environmental Management Plan. The project involved an extensive public review phase

with residents, various departments within the City of Vancouver, and environmental, nongovernment organizations (NGOs).

Engineering Features:

Construction of the marsh started in the summer of 1992, and transplanting was completed in March 1993. The marsh habitat banking component of the Fraser Lands Riverfront Park is completed, but there is still some upland park work to be finished. The marsh habitat bank involved constructing a rock berm to hold marsh soils, trucking sand and topsoil to the site and premixing them to fabricate marsh soil, placing and grading marsh soil, harvesting donor vegetation from approved donor sites, and transplanting the vegetation at the compensation area. The Fraser Lands Marsh was designed to have a sand base overlayed by approximately 7.9 inches of fabricated marsh soil (i.e., sand and topsoil). This design was adopted to provide a suitable upper soil layer for plant establishment and a coarser base to support heavy construction equipment. At the upstream site, upland was excavated to remove former industrial soil.

Existing ground elevations were found to be lower than those recorded in the surveys done a couple of years prior at the beginning of the preliminary design phase of the project. This affected the cost and location of the rock berm. Some minor settling caused a small section of the marsh to fall below intended elevations for Lyngby's sedge. Sand was pumped and raked into the site, and the sedge was replanted.

Monitoring Techniques:

Currently, the habitat bank is being monitored for stability and vegetation establishment. Wetland compensation is administered by the DFO, but there is no standardized monitoring procedure equivalent to HEP or WET. There is a habitat compensation agreement that requires monitoring to be conducted for five years, and the proponent is required to undertake remedial measures. The program is to be conducted until the vegetation coverage of the habitat compensation marsh is similar to that of the control marsh. Success is determined by DFO as 75 to 80 percent coverage of the compensation site by vegetation within the five-year term of monitoring. Once the marsh is "successful," the area could be used for habitat banking purposes.

The monitoring program involved observations on site stability, a post-construction elevation survey, and a soil analysis and vegetation study using transects and one-square-meter (1.196 square yard) plots for percentage of vegetation cover and shoot density for the target species. Soil sampling was included in the monitoring program, because no data exist for marsh soils of the Fraser River. Soil data will be used to assist future design of compensation projects. General observations are made throughout each growing season from March to September. Intensive soil and vegetation sampling is done once per year in late July, at the time when biomass is predicted to be at a peak. Thus far, the monitoring program has been effective in providing quantitative data on sedge density and semiquantitative data on plant coverage. The soil data appear to be effective for assessing

physical characteristics such as particle size, bulk density, percentage of organic matter, and pH. Nutrient data (e.g. percentage of carbon, nitrogen, ammonia, nitrate/nitrite, phosphorus) and cations (e.g. magnesium, calcium, potassium, sodium) are more difficult to interpret because of small sample size and variability. Preliminary indications are that the habitat bank is performing well, as evidenced by the vegetation colonizing the site. Measurements of vegetation above ground biomass will be conducted in 1995 to make the coverage data more quantitative.

Cost Analysis:

The total cost of the North Fraser Harbour project is $389,697 (1992 Canadian dollars) (Table IV.29). The project involved the creation of Glaston Park (1.92 acres) and Kerr Street (0.74 acres) marshes, both part of Fraser Lands. Costs include the direct costs of construction of a rock berm to hold marsh soils; fabrication; trucking, placement, and grading of soil; harvest, trucking, and transplanting of donated vegetation; removal of former industrial soil; engineering design; monitoring; and replanting (due to minor settling at one section of marsh). All costs are reported as installed costs (including labor and capital). Four percent ($13,232) of the direct construction costs is reported as change order agreements due to unexpected excavation and fill needs.

TABLE IV.29. Cost by Component, Fraser Lands Habitat (Canadian dollars)

| Project Component | Quantity | Unit | Equipment, Materials, Supplies, etc. | Labor | Total Costs ($1992) |
|---|---|---|---|---|---|
| Marsh sandfill | 13,572 | tons | $135,720 | | $135,720 |
| Marsh berm armour stone | 4,631 | tons | $76,844 | | $76,844 |
| Marsh berm filter stone | 4,417 | tons | $58,493 | | $58,493 |
| Marsh cut | 2592 | cu m | $10,368 | | $10,368 |
| Outfall ditch excavation | 624 | cu m | $4,992 | | $4,992 |
| Outfall ditch armour stone | 300 | tons | $5,700 | | $5,700 |
| Outfall ditch filter stone | 754 | tons | $11,310 | | $11,310 |
| Marsh transplant | | LS | $29,600 | | $29,600 |
| C.O. asphalt removal | | LS | $3,570 | | $3,570 |
| C.O. excavation | 300 | sq m | $600 | | $600 |
| Engineering design | | LS | $30,000 | | $30,000 |
| Replanting | 260 | sq m | $2,500 | | $2,500 |
| Monitoring | | LS | $20,000 | | $20,000 |
| **Total** | | | $389,697 | | **$389,697** |

Sources:

Anonymous. 1993. "North Fraser Harbour Habitat Compensation Bank." Memorandum of Understanding Concerning Procedures for Operation of the North Fraser Harbour Habitat Compensation Bank Between the North Fraser Harbour Commission and Department of Fisheries and Oceans. Available from North Fraser Harbour Commission, Richmond, British Columbia.

Williams, G.L. 1994. *North Fraser Harbour Fraser Lands Compensation Bank 1994 Monitoring Report.* Prepared by G.L. Williams & Associates, Ltd., for North Fraser Harbour Commission, Richmond, British Columbia.

# *V. SUMMARY AND RECOMMENDATIONS*

## GENERAL SUMMARY

Thirty-nine case studies were developed from an initial list of over 200 potential projects from various geographic areas throughout the United States. Some of the projects were components of programs that have a large number of similar projects. The projects were categorized into 16 types that reflect the primary features of these projects and they include bottomland hardwood forest restoration, fish and wildlife habitat enhancement, estuarine wetland creation, estuarine wetland enhancement, estuarine wetland restoration, estuarine wetland restoration and wildlife enhancement, mitigation bank establishment, stream enhancement, stream restoration, water quality remediation, wetland creation, wetland creation and enhancement, wetland enhancement, wetland mitigation, wetland restoration, and wetland restoration and enhancement.

Because one of the purposes of this report was to provide cost information on restoration methods, the projects included in this report were largely successful in meeting their goals. However, despite concerted and expensive attempts, many restoration projects fail to meet performance goals (NRC 1992). Perhaps the most common reason for failure is lack of adequate understanding of the environmental conditions at the restoration site. The projects reviewed here generally had very good information on the site, which was gathered during the planning phase. The site analysis phase of a project is both highly important for this purpose and can be one of the most expensive phases of the project.

The primary goals of the projects were reestablishing historical vegetation, restoring or enhancing habitat for wildlife and fish species, stabilizing shorelines, controlling mosquitoes, treating wastewater, and restoring hydrology. Engineering features covered activities ranging from projects involving very little action to highly engineered projects involving extensive reworking of the physical and hydrological conditions of the system.

Monitoring techniques also ranged from the very general, such as observations and photographs taken annually, to highly quantitative studies involving physical, chemical and biological sampling. This broad range indicates that although standardized techniques exist, they have not been widely applied. All projects with monitoring information covering more than one year indicated some level of success. Success was assessed relative to goals and criteria for the projects. Hydrology, plant growth and cover, and bird use were most often cited as clear indicators of the performance of the system.

The study attempted to derive estimates of the cost of equipment, labor, materials, supplies, and "other" for each component of a project from a representative sample of 39 wetland and habitat restoration projects across the United States. In many cases, the institutional knowledge about a project no longer existed or files including cost information were no longer available. In many cases,

project costs were reported in the initial project budget with no detailed accounting of actual expenditures, such as change orders, delays, salary and wage increases, among others. Although many project contacts eagerly report "costs," it appears that they were unaware of the source of these figures, the method of their assessment, or the repercussions of inaccurate and hidden restoration costs. Hidden costs, such as project management, overhead, and volunteer labor, were typically missing from reported costs. As a result, final total costs estimates are probably underestimates of the true costs of the various projects analyzed. The costs for units of various actions and materials are summarized for comparative purposes. These data can be used to generate the range of costs likely associated with specific restoration efforts, but the accuracy of costs must be verified prior to finalization of a restoration project budget.

There is a clear need to develop much more complete and consistent documentation of all aspects of restoration projects. This is especially true if it becomes a national focus for Federal agencies. Projects currently are largely constructed on an individual basis with little impetus to follow set methods or guidelines for establishing goals, performance criteria, and monitoring. Costing (see Section IV) was poorly documented in some cases or was not accessible in other cases, even after considerable effort. This lack of information hinders the ability to develop the technologies for restoration, which in turn limits the predictability of actions undertaken during restoration projects.

A consistent observation made by those involved in these efforts is that each project was to a certain degree an experiment. Because of the lack of understanding about what initial conditions must be created to achieve a predictable and desirable system, there was considerable uncertainty associated with most restoration projects. Contacts often cited the lack of funding and impetus to long-term monitoring as the most serious impediment to furthering our understanding of how to "engineer" restoration. These inherent problems were compounded by the fact that aquatic and wetland systems are exceedingly complex; they are more complex to understand, design, or rebuild than physical structures, such as bridges.

## PROJECT PLANNING RECOMMENDATIONS

There is a growing restoration "ethic" nationally and globally. If restoration becomes a part of the mission of agencies, a unified method for planning and implementing restoration projects would facilitate development of the technology for restoration. Typically, there are four primary phases of a restoration project. These are as follows:

1. planning and design

2. construction

3. assessment and adjustment

4. documentation and communication.

Planning and design consists of establishing goals and objectives for the project. Goals for the project are the critical element of any restoration effort. The goals drive all other aspects of the project. A goal statment is generally one sentence long and identifies the vision for the project. An example of a goal statement is as follows:

"The goal of the project is to reestablish tidal marsh communities to Site A." This may be accomplished through reestablishing natural tidal hydrology and removing other major impediments to marsh development.

Establishing a model system, preferably very near the system to be restored, will assist in understanding what types of actions are needed to restore the system and what the system is expected to look like after a period of development following physical changes.

In addition, performance criteria are established. Criteria often include such items as time scale, spatial scale, structural conditions, functional conditions, self-sustaining potential, and potential resilience of the system to disturbance. Site selection is also part of planning. This involves examination of the historical (predisturbance) conditions, degree of present alteration, present ecological conditions, etc. The type of system to be restored is also determined in planning. Level of physical effort, cost, schedule, contingency plan, and engineering design are all part of planning.

The construction phase consists of any pre-assessment (e.g., level of contamination) required prior to construction, as well as the actual construction of the project. Construction must be monitored by someone who is intimately aware of the goals of the project. This is to ensure that decisions can be made during construction that result in significant improvement of the project toward its goals. Mistakes made during construction often occur. In system where a few centimeters may have a significant impact on the hydrology, construction must be monitored carefully.

During the assessment and adjustment phase, the monitoring program is used to assess progress toward the goals through use of the performance criteria. If deviation from the predicted trajectory of development is seen, adjustments can and should be made. Decisions on what level of adjustment to make should be made through review by persons knowledgeable about the project. This phase of the project is often referred to as the adaptive management phase. It acknowledges that natural processes will ultimately dictate the trajectory of development of the system, and that any physical alterations required to assure that the system meets the goals for the project should be carried out with the understanding of how nature is altering the system. An underlying goal of any restoration project should be self-maintenance. That is, the system should be designed to develop naturally toward the goal without expensive and highly invasive maintenance actions.

The present study was clearly hindered by poor project documentation. In the documentation and communication phase, all aspects of the project should be documented. Accurate and consistent record keeping is useful for documenting the effects of decisions and for showing progress toward goals. Communicating how well the system performed relative to the goal of the project, and using data acquired through monitoring and with reference to the performace criteria, is essential. This type of information is critical to help minimize cost and maximize the probability for success of future projects. Our review of projects indicated that record keeping was given low priority in many projects. It is imperative that the information on the project be disseminated as widely as possible.

## COST ANALYSIS DISCUSSION

A number of previous attempts have been made to analyze wetland restoration costs (King and Bohlen 1994, NOAA 1992, Guinon 1989, U.S. Department of Interior 1991). In these studies, cost estimates are assessed on a total-per-acre basis and reported in constant cost dollars. King and Bohlen (1994) report estimates of average wetland restoration costs (excluding land costs) derived from primary data (90 wetland restoration projects - primarily mitigation projects performed by developers) for various project categories including aquatic bed, complex, freshwater (FW) mixed, FW forested, FW emergent, tidal FW, salt marsh, mangroves, and agricultural conversion (King and Bohlen 1994, Figure 1, p.4). Table 1 (King and Bohlen 1994, p.5) provides further statistical details, including average, median, minimum, and maximum observed project costs in each category. It also shows the allocation of costs by construction stage (preconstruction, construction, and post-construction), and by input category (labor, equipment, material, and other). King and Bohlen (1994) report that the cost of wetlands restoration is not uniform. Costs appear to depend on what is being restored; how badly it is damaged; and how fast, how complete, and how permanent the repairs need to be. Records of wetland mitigation costs gathered for their study ranged from $5 per acre to $1.5 million per acre.

Guinon (1989) presents results of a field implementation cost survey of 25 wetland restoration projects throughout California and illustrates a wide variation in costs ($1,626 to $240,000 per acre) (Guinon 1989, Tables). Components assessed in this study are grading and filling, soils, nonorganic debris removal, vegetative material clearing and removal, chemical plant eradication, erosion control, seed and plant procurement, plant establishment, plant protection, installation of temporary irrigation, irrigation, erosion maintenance and weed control, replanting, monitoring, and project management. The cost of individual components by project is not reported. According to Guinon (1989), there are no universally accepted standards for reporting mitigation costs. However, for meaningful equitable comparisons between projects or alternative, industry standard costs can be readily defined. The material difference between public agency and private developer cost is profit, which can range from 15 to 20 percent. The overhead efficiencies experienced by a private firm can offset this difference.

NOAA (1992) summarizes some costs of typical wetland creation projects (NOAA 1992, Table 3.3, p.3/16). The reported costs for these projects have been adjusted to 1992 dollars. The

cost figures presented here are for projects that typically had either no or minimal planting. Thus, planting costs should be added to the costs reported. The costs of restoration projects presented in this study range from $196 to over $28,000 per hectare. Although this is a wide range of costs, it does not represent the extremes. According to NOAA (1992), restoring some wetlands in urban areas has been estimated to cost considerably more than the highest cost reported here.

The U.S. Department of Interior (1991) presents the results of a comprehensive review of the available literature on wetland creation and restoration and wetland mitigation plans, including estimates of the costs associated with various types of restoration projects. The wetland restoration costs found in the literature included some estimates of overall costs per acre and of costs for specific restoration tasks. The range of overall restoration costs, updated to 1989 dollars, is approximately $2,000 to $50,000 per acre, although one study showed costs of $220,000 per acre. The U.S. Department of Interior report suggests that this variation could exist, in part, because there is no "typical" or standard restoration project. As indicated in Exhibit 7-11 (U.S. Department of Interior 1991, pp. 7/37-7/41), a restoration project can require over 20 components or activities. Some projects could omit entire phases; others could require special treatment and long-term monitoring, which adds significantly to total project costs. The U.S. Department of Interior (1991) also suggests that the studies from which the cost estimates were taken frequently claim that the projects investigated were under-funded, haphazardly planned, and poorly executed, and could have been designed with no specific goals in mind. Many of the studies also included qualifiers, pointing out that they did not include some costs, or included others that could not be separated from the costs of the development project that necessitated the mitigation. According to U.S. Department of Interior (1991), the empirical estimates of wetland restoration costs in the available literature are generally of poor quality.

In an attempt to overcome some of the past limitations of restoration cost estimation efforts, attempts were made to derive estimates of the cost of equipment, labor, materials, supplies, and other items for each component of a project from a representative sample of 39 wetland and habitat restoration projects across the United States and two from Canada. Individual project contacts were asked to respond to the following questions (within the context of the overall survey):

1. What was the price of the engineering design?

2. What was the cost of monitoring the program?

3. What physical structures were built? How many of each? What was the cost? Year costed?

4. What were the labor costs associated with each major aspect of the project?

5. Are there maintenance requirements for physical conditions or structures? What is the cost of these?

6. Who paid for this program?

In many cases, project costs were reported only as the initial project budget, with no detailed accounting of actual expenditures including, for example, change orders, delays, salary and wage increases and other items. Follow-up phone calls were used to elicit information on the true costs of selected projects, including the opportunity cost of individual's time and donated or contributed labor and equipment. Although many project contacts eagerly reported "costs," they seemed to be unaware of the source of these figures, how they were assessed, or the repercussions of inaccurate and hidden restoration cost. All too frequently, costs were reported out of context, resulting in misinformation. "Reported" cost figures often did not include costs for land acquisition, permitting, planning, design, maintenance, and monitoring. Most costs were reported as "installed" or lump sum. As a result, separate labor, equipment, and material costs for a project component were not available. In addition, with the lack of unit descriptions, estimations of costs per unit were not possible. Furthermore, hidden costs such as project management, overhead, and volunteer labor were typically missing from reported costs. As a result, final total costs estimates are probably, on balance, underestimates of the true costs of the various projects analyzed.

Cost data in this study were collected on the component level with respective unit descriptions, which made comparison of the cost estimates from our study with those found in the literature mentioned above very difficult. Additionally, because of the many elements associated with the restoration projects analyzed in this study, and because costs were allocated in different ways in the projects reviewed, statistically significant comparisons of the costs of specific components was not possible. Table V.1 offers a list of components that appeared more than once in our sample for which total and per unit costs were reported. These components include gravel enhancement, riprap installation, culvert installation, channel cleaning, erosion control, dike removal, dike/dam/levee building, vegetation/planting, and access facilities. Gravel removal activity costs range from \$3.27 to \$3,239 per ton. Riprap installation costs range from \$5.00 to \$19.00 per ton. Culvert installation costs range from \$150 (for 48-inch-diameter culvert) to \$1,103.85 per foot. Channel cleaning costs range from \$4.00 to \$8.00 per cubic meter. Erosion control costs range from \$1.40 to \$4.00 per square foot. Dike removal costs range from \$1.92 to \$2.67 per foot. Dike/dam/levees construction costs range from \$5.00 to \$20.00 per linear foot. The range of subcomponents of vegetation and replanting and access facilities makes comparison extremely difficult.

There are two primary variables determining wetland restoration costs: 1) the specific project components required to restore the wetland, from conceptual design to monitoring; and 2) how the restoration costs are allocated and reported. Costs of implementing restoration projects are unique to each project and are significantly influenced by site access, grading, and site preparation requirements, difficulty of plant community establishment, schedule delays, and complexity of habitat management programs. Other factors affecting final restoration costs are as follows: 1) economies of scale, 2) type of restoration; 3) restoration design; 4) restoration site quality; 5) adjacent site quality; 6) appropriate technology; 7) simultaneous construction multiple use; and 8) project management (Guinon 1989). As stated by Guinon (1989), when reporting, analyzing, and comparing

restoration costs, considering the project scope and identifying all project elements included or excluded from reported figures was essential. The scope of this study and inadequate nature of contact responses did not allow adequate inquiry about all significant components of each project on a per unit basis, assess costs in context, or specify all those project elements not reported by the project contact.

It is strongly recommended that as part of the project plan, a worksheet for cost information be developed. This worksheet should have space for entering all cost items relevant to the project. The items can be divided into categories of planning and design, construction, assessment and documentation, and communication. Subcategories such as labor, materials, supplies, travel, equipment should also be included under each category. Since a number of projects made use of volunteer labor, costs for coordinating and training volunteers also should be specified. It would be useful to estimate a unit (per-hour) cost for volunteer labor to help quantify the savings represented by the use of such donated efforts. Finally, the accounting of the project needs to be updated as appropriate throughout the life of the project. All accounting should be kept in the same file or database with all other project information. This allows people unfamiliar with the project to easily access all pertinent information.

## TABLE V.1. Common Components and Costs

(italicized projects do not have an associated economic data table)

| Component And Project | Item | Quantity | Units | Total Costs ($1994) |
|---|---|---|---|---|
| Gravel Enhancement Projects (mostly in California) | | | | |
| *Camanche (1990)* | | 76 | | $22,448 |
| *Camanche (1992)* | | 230 | | $6,587 |
| *Shasta (1988)* | | 76,410 | | $310,017 |
| *Shasta (1990)* | | 12,226 | | $2,469,319 |
| *Shasta (1991)* | | 6,113 | | $21,326,432 |
| *Los Padres (1990)* | | 31 | | $651 |
| *Los Padres (1990)* | | 612 | | $92,038 |
| *Iron Gate (1985)* | | 1,666 | | $185,420 |
| *Kent (Peter's)(1991)* | | 41 | | $862 |
| *Courtwright (1985)* | | 5 | | $16,361 |
| *Clair Eagle (Trinity) (1989)* | | 1,490 | | $26,027 |
| *Folsom (1991)* | | 764 | | $32,313 |
| *Lee Vining Creek (1991)* | | 229 | | $4,631 |
| *Grant Lake (1991)* | | 917 | | $19,388 |
| Riprap Installed in Projects | | | | |
| Upper Little Swatara (1987) | | 400 | T | $2,583 |
| *Doran Beach (1993)* | | 20 | cy | $2,870 |
| *Cowlitz (1986)* | | 100 | cy | $669 |
| Des Plaines (1985) | Experimental Wetland | 1,050 | std cy | $14,316 |
| Des Plaines 2 (1985) | | 20 | std cy | $277 |
| Metzger Marsh (1994) | | NA | NA | $184,900 |
| Rainey Creek (1993) | | 2,000 | cy | $61,509 |
| Culvert Installation | | | | |
| San Leandro (1994) | 48-in. culvert | 260 | ft (4 @ 65 ft) | $287,000 |
| San Leandro (1994) | 24-in. culvert | 30 | ft (1 @ 30 ft) | $11,500 |
| Des Plaines (1985) | 18-in. culvert | 130 | ft | $3,190 |
| Des Plaines (1985) | 24-in. culvert | 240 | ft | $7,853 |
| Des Plaines (1985) | 30-in. culvert | 30 | ft | $1,350 |
| Des Plaines (1985) | 36-in. culvert | 160 | ft | $9,162 |
| *Doran Beach (1993)* | 48-in. culvert | 38 | ft | $5,843 |
| Kennedy Park | 24-in. culvert | 105 | ft | $4,521 |
| Triangle Marsh | Culvert | 6 Total | ft (2@3 ft, 2@2 ft, 2@18 in). | $101,343 |
| Indian River | 30-in. culvert | 11 Total | 25 ft | $18,712 |

TABLE V.1. (Continued)

| Component And Project | Item | Quantity | Units | Total Costs ($1994) |
|---|---|---|---|---|
| Culvert cleanout and removal | | | | |
| *Doran Beach (1993)* | 24-in. culvert | 38 | ft | $1,025 |
| Channel Cleaning | | | | |
| Tryon Creek | | 10,000 | cy | $52,631 |
| Mill Creek Channel | 4- by 12-ft box culvert | 16 | ea | $10,460 |
| Erosion Control | | | | |
| Prairie Creek | Fencing and revegetation | 1 | mile | $104,525 |
| Vegetation/Planting | | | | |
| Shaker Trace (1994) | native grasses | 20 | hectares | $2,000 |
| SCS1 (1994) | trees | 12 | acres | $3,888 |
| SCS1 (1994) | clumps, shrubs | 42 | clumps,shrubs | $882 |
| SCS2 (1994) | trees | 8 | acres | $2,592 |
| SCS2 (1994) | clumps, shrubs | 27 | clumps, shrubs | $567 |
| SCSA (Snohomish County) (1994) | Tree Planting | 6 | acres | $3,000 |
| SCSA (Snohomish County) (1994) | Shrub Planting | 78 | clumps | $1,950 |
| Clinton County (1994) | move intact wetland | 0.5 | acre | $182,000 |
| Des Plaines (1985) | Experimental Wetlands | 237 | acres | $577,877 |
| *Cowlitz (1986)* | Corn | 1 | acre | $241 |
| *Cowlitz (1986)* | Wheat | 1 | acre | $234 |
| *Cowlitz (1986)* | Wheat and corn | 1 | acre | $268 |
| *Cowlitz (1986)* | Small, irregular patches | 1 | acre | $402 |
| | Conifers | 1 | acre, 1,325 stems/acre +10% | $95 |
| | Others | 1 | acre, 625 stems per acre | $414 |
| | Planting machine | 1 | acre, $50/1,000 stems | $88 |
| | Preplant labor | 1 | acre | $120 |
| | Fertilizer | 1 | acre, 160 lb 10-10-20 | $21 |
| | Seed | 1 | acre, $69/31.46 lb | $92 |
| | Replant conifers | 1 | acre, 400 stems | $27 |
| | Replant others | 1 | acre, 190 stems | $115 |
| | Planting, hand | 160 | acres, $160/1000 | $86 |

TABLE V.1. (Continued)

| Component And Project | Item | Quantity | Units | Total Costs ($1994) |
|---|---|---|---|---|
| Culvert cleanout and removal | | | | |
| Cowlitz (1986) | Tall shrub planting | | | |
| | Shrubs | 1 | acre, 2,725 stems per acre | $1,806 |
| | Planting machine | 1 | acre, $50/1,000 stems | $182 |
| | Preplant labor | 1 | acre, 2 hr/acre | $120 |
| | Fertilizer | 1 | acre, 160 lbs 10-10-20 | $21 |
| | Seed | 1 | acre, 31.46 lb | $92 |
| | Shrub replant | 1 | acre, 820 stems/acre | $494 |
| | Planting, hand | 160 | acres, $160/1,000 | $175 |
| *Cowlitz (1986)* | Phreatophyte planting[a] | | | |
| | Phreatophytes | 1 | acre, 1,375 stems per acre | $912 |
| | Planting (hand) | 1 | acre | $294 |
| | Spraying | 1 | acre | $92 |
| | Replant | 1 | acre, 420 stems | $253 |
| | Planting, hand | 160 | acres, $160/1,000 | $90 |
| *Cowlitz (1986)* | Low shrub planting | | | |
| | Blackberry seed | 1 | acre, 0.2 lb/acre | $24 |
| | Preplant labor | 1 | acre, 2 hr | $120 |
| | Fertilizer | 1 | acre, 160 lb 10-10-20 | $21 |
| | Seed mix | 1 | acre, 31.46 lb | $92 |
| *Cowlitz (1986)* | Pasture reseeding | | | |
| | Red clover | 1 | acre, 8 lb | $21 |
| | Orchard grass | 1 | acre, 3 lb | $7 |
| | Gray oats | 1 | acre, 50 lb | $9 |
| Palo Alto | Irrigation system | 1 | LS | $5,751 |
| | Topsoil, plain | 102 | cy | $3,660 |
| | Topsoil, mix | 370 | cy | $13,347 |
| | Weed control rings | 903 | ea | $1,888 |
| | Buffer plants | 903 | ea | $4,107 |
| | Marsh plants (Spartina) | 1,590 | ea | $14,963 |
| | Marsh plants (Grindelia) | 392 | ea | $1,640 |
| | Disking | 17,327 | sq yd | $3,080 |
| | Siltfence | 1,990 | ft | $6,242 |
| Tryon Creek | Trees, cuttings | 16,805 | stems | $20,364 |
| | | 13,805 | trees | _[b] |
| | | 3,000 | cuttings | _[b] |
| Dike Removal | | | | |
| Salmon River | | 6,000 | ft | $20,662 |
| Salmon River | | 2,600 | ft | $6,457 |

TABLE V.1. (Continued)

| Component And Project | Item | Quantity | Units | Total Costs ($1994) |
|---|---|---|---|---|
| Dike/Dam/ Levee Building | | | | |
| Rainey Creek (1993) | Excavation | 11,200 | cy | $59,664 |
| Des Plaines 1 (1993) | Excavation | 210,500 | cy | $431,591 |
| Des Plaines 2 (1986) | Excavation | 100,200 | cy | $268,236 |
| Des Plaines 3 (1986) | Excavation | 4,100 | cy | $8,232 |
| Des Plaines 4 (1986) | Excavation | 1,600 | cy | $4,283 |
| San Leandro (1994) | Repair levee, 3 ft high | 200 | ft | $4,000 |
| San Leandro/Roberts Landing (1994) | Raise existing levee to grade | 900 | ft | $6,300 |
| Shaker Trace (1991) | Dike construction | 10 | ea | $43,084 |
| Kennedy Park | Asphalt concrete dike | 118 | ft | $605 |
| Cattle Fencing | | | | |
| Tryon Creek | | 13,500 | ft | $27,291 |
| Access Facilities | | | | |
| Palo Alto | Stock pile embankment | 49,422 | cy | $48,059 |
| | 2-in. decomposed granite on 4-ft aggregate base | 14,540 | sq ft | $13,074 |
| | 2-in. AC, 6-ft aggregate base | 1,320 | sq ft | $6,901 |
| | Asphalt concrete berm | 130 | ft | $408 |
| | Retaining wall and handrail | 140 | ft | $34,232 |
| | Retaining wall | 124 | ft | $20,408 |
| | Bollards | 98 | ea | $6,148 |
| | Cable | 1,520 | ft | $3,179 |
| | Detail 39&39A striping | 50 | ft | $52 |
| | 12-in. solid line | 50 | ft | $52 |
| | Pavement marking | 4 | ea | $52 |
| | Directional sign | 1 | ea | $2,091 |
| | Park bench (double) | 3 | ea | $2,847 |
| | Park bench (single) | 7 | ea | $3,227 |
| | Bike rack bollard | 6 | ea | $502 |
| | Trash receptacle | 7 | ea | $6,820 |

(a) Phreatophyte is a deep-rooted plant, such as willow, that draws from a water supply near the water table.
(b) Trees, stems, and cuttings costs are combined in one figure.

# *VI. LITERATURE CITED*

The references listed in this section were those not previously listed with project descriptions in the report (Section IV).

Guinon, M. 1989. *Project Elements Determining Comprehensive Restoration Costs and Repercussions of Hidden and Inaccurate Costs.* Paper Presented to Society for Ecological Restoration and Management Annual Meeting, Oakland, California.

King, D.M., and C.C. Bohlen. 1994. "Estimating the Costs of Wetland Restoration." *National Wetlands Newsletter* 16(3):3-8.

NOAA (National Oceanic and Atmospheric Administration). 1992. *Restoration Guidance Document for Natural Resource Injury as a Result of Oil Spills.* National Oceanic and Atmospheric Administration, Washington, D.C.

NRC (National Research Council). 1992. *Restoration of Aquatic Ecosystems.* National Academy Press, Washington, D.C.

Shreffler, D.K., and R.M. Thom. 1993. *Restoration of Urban Estuaries: New Approaches for Site Location and Design.* Final Report to Washington State Department of Natural Resources. Battelle Pacific Northwest Laboratories, Richland, Washington.

U.S. Department of Interior. 1991. *Estimating the Environmental Costs of OCS Oil and Gas Development and Marine Oil Spills: A General Purpose Model.* Report prepared by A.T. Kearney, Inc. for U.S. Department of Interior, Minerals Management Service, Washington, D.C.

# *APPENDIX A. ADDITIONAL PROJECT CONTACTS*

During the course of the review, several publications that could be of use in further development of engineering and cost aspects of restoration projects were located. In this section, the most relevant of these are identified.

<u>Fish Habitat Enhancement. A Manual for Freshwater, Estuarine and Marine Habitat</u>.
Mark A. Adams and Ian W. Whyte
ECL Envirowest Environmental Consultants, Ltd.
New Westminster, B.C., Canada
(604) 521-6500

This is a comprehensive and well-illustrated manual that reviews a variety of methods for fish habitat enhancement. The report features several project examples that include photographs and line drawings. The technologies covered are bank stabilization, riparian planting, streambank fencing, gravel catchment and placement, gravel cleaning, artificial spawning channels, artificial incubators, mainstream rearing habitat, off-channel development, food production, obstruction removal, culverts, fishways, fish screws, streamflow control, stream aeration, marsh creation, access improvement, woody debris and erosion protection, transplanting eelgrass, and artificial reef creation.

<u>Bottomland Hardwood Reforestation in the Lower Mississippi Valley</u>.
James A. Allen
National Wetlands Research Center
U.S. Department of Interior
Fish and Wildlife Service
Slidell, LA

Harvey E. Kennedy, Jr.
Southern Forest Experiment Station
U.S. Department of Agriculture
Forest Service
Stoneville, MS

Topics covered in this small manual include choosing the planting site, choosing the species, choosing the planting method, site preparation, seeding methods, seed storage, seedling handling and planting, and post-planting activities. The book has line drawing and photographs that illustrate the various methods.

Wetland Creation and Restoration.
Jon A. Kusler, Editor
Association of State Wetland Managers
Berne, NY

Mary E. Kentula, Editor
U.S. Environmental Protection Agency
Corvallis, OR

The book represents the most comprehensive review of wetland restoration to date. Although published in 1990, the book is still very useful in describing case studies of wetland restoration and summarizing all aspects of these efforts. Projects are reviewed on a regional basis, which provides a somewhat natural division of types of wetland (e.g., coastal plain, palustrine). Methods and technologies for restoration are illustrated for the case studies. Monitoring results are also provided. Cost analysis is not provided in detail for any of the projects.

Restoring the Nation's Marine Environment.
Gordon W. Thayer, Editor
National Oceanic and Atmospheric Administration
Beaufort, NC

This book is a compendium of papers on coastal restoration. It resulted from a meeting in Washington, D.C. that was held to initiate NOAA's Office of Restoration, and covers topics including cordgrass restoration, tidal marshes of North Carolina, seagrass restoration, coral reef restoration, mangrove restoration, kelp forest restoration, stream habitat restoration, restoration of rivers damaged by dams, restoration in urbanized estuaries of the Pacific Northwest, and restoration of areas damaged by oil spills. Case studies are used heavily in all of the chapters. No costing information is presented.

A Guide to Wetland Functional Design.
Anne D. Marble
Anne D. Marble & Co.
Rosemont, PA

This guidebook presents concise summaries of methods to enhance the functionality of wetland systems. It is written in guidebook style so that an individual can easily find a short section on how, for example, to increase aquatic diversity. The book is based on the WET.

An Approach to Improving Decision Making in Wetland Restoration and Creation.

Mary E. Kentula
U.S. Environmental Protection Agency
Corvallis, OR

Robert P. Brooks
The Pennsylvania State University
University Park, PA

Stephanie E. Gwin
Cindy C. Holland
Arthur D. Sherman
Jean C. Sifineos
ManTech Environmental Technology, Inc.
Corvallis, OR

This is a guidebook that focuses on comparisons between natural and created wetlands to determine whether restored wetlands successfully replace wetlands lost to development and other pressures. The guide presents clear and concise methods for selection of sites and for acquisition of information needed to make comparisons. The book stresses the need to completely document projects to improve restoration technology.

## *APPENDIX B. LIST OF PLANTS MENTIONED IN TEXT*

| | |
|---|---|
| alder | *Alnus* spp. |
| American elm | *Ulmus americana* |
| arctic rush | *Juncus arcticus* |
| arrow-grass | *Triglochin maritimum* |
| bald cypress | *Taxodium distichum* |
| bentgrass | *Agrostis* spp. |
| big leaf maple | *Acer macrophyllum* |
| bishop pine | *Pinus muricata* |
| blackberry | *Rubus* spp. |
| black cottonwood | *Populus trichocarpa* |
| blue vervain | *Verbena hastata* |
| boneset | *Eupatorium perfoliatum* |
| brass buttons | *Cotula coronopifolia* |
| broad-leaf arrowhead | *Sagittaria latifolia* |
| bulrush | *Scirpus* spp. |
| bushy seed box | *Ludwigia alternifolia* |
| canarygrass | *Phalarus* spp. |
| Carolina ash | *Fraxinus caroliniana* |
| cattail | *Typha latifolia* |
| clammy hedge-hysop | *Gratiola neglecta* |
| clover | *Trifolium* spp. |
| coast redwood | *Sequoia sempervirens* |
| common buttonbush | *Cephalanthus occidentalis* |
| common cocklebur | *Xanthium strumarium* |
| common reed | *Phragmites communis* |
| common velvetgrass | *Holcus lanatus* |
| conobea | *Conobea multifida* |
| cordgrass | *Spartina alterniflora* |
| dahoon holly | *Ilex cassine* |
| ditch stonecrop | *Penthorum sedoides* |
| Douglas fir | *Pseudotsuga menziesii* |
| duckweed | *Lemna* spp. |
| dwarf alkaligrass | *Puccinellia pauciflora* |
| English maple | *Acer pseudoplatanus* |
| European birch | *Betula pendula* |
| false dragon-head | *Physostegia virginiana* |
| false pimpernel | *Lindernia anagallidea* |
| fen aster | *Aster puniceus* |
| grand fir | *Abies grandis* |

| | |
|---|---|
| great blue lobelia | *Lobelia siphilitica* |
| green ash | *Fraxinus pennsylvanica* |
| gumweed | *Grindelia* spp. |
| incense cedar | *Calocedrus decurrens* |
| knotgrass | *Paspalum distichum* |
| laurel oak | *Quercus laurifolia* |
| Lyngby's sedge | *Carex lyngbyei* |
| maidencane | *Panicum hemitomon* |
| marsh seedbox | *Ludwigia palustrus* |
| monkey flower | *Mimulus* spp. |
| mountain ash | *Sorbus sitchensis* |
| nodding beggar tick | *Bidens cernua* |
| Norway maple | *Acer platanoides* |
| Pacific silverweed | *Potentilla pacifica* |
| pickleweed | *Salicornia virginica* |
| pond cypress | *Taxodium ascendens* |
| ponderosa pine | *Pinus ponderosa* |
| prairie cordgrass | *Spartina pectinata* |
| pungent bulrush | *Scirpus pungens* |
| red maple | *Acer rubrum* |
| red osier dogwood | *Cornus stolonifera* |
| red top | *Agrostis alba* |
| reed canarygrass | *Phalarus arundinacea* |
| reed | *Phragmites* spp. |
| rush | *Juncus* spp. |
| ryegrass | *Lolium* spp. |
| saltbush | *Atriplex patula* |
| saltgrass | *Distichlis spicata* |
| saltmarsh hay | *Spartina patens* |
| saltmarsh birdsbeak | *Cordylanthus* spp. |
| saltmarsh sandspurry | *Spergularia marina* |
| Scotch pine | *Pinus sylvestris* |
| sedge | *Carex* spp. |
| Sitka spruce | *Picea sitchensis* |
| slender millet | *Panicum virgatum* |
| soft rush | *Juncus effusus* |
| softstem bulrush | *Scirpus validus* |
| spike rush | *Eleocharis* spp. |
| St. Johnswort | *Hypericum mutilum* |
| stalking yellow cress | *Rorippa sessiliflora* |
| swamp milkweed | *Asclepias incarnata* |
| swamp bay | *Persea palustris* |

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|---|---|
| swamp lousewort | *Pedicularis lanceolata* |
| sweetbay magnolia | *Magnolia virginana* |
| sweetgum | *Liquidambar styraciflua* |
| umbrella sedge | *Cyperus* spp. |
| water birch | *Betula fontinalis* |
| water oak | *Qercus nigra* |
| water pimpernel | *Samolus parviflorus* |
| water plantain | *Alisma subcordaturn* |
| wild cenna | *Cassia hebecarpa* |
| wild rose | *Rosa* spp. |
| willow | *Salix* spp. |
| wool-grass | *Scirpus cyperinus* |
| yellow sweet clover | *Melilotus officianalis* |

# *APPENDIX C. STREAM ENHANCEMENT PROJECTS FROM KONDOLF AND MATTHEWS (1993)*

TABLE C.1. Gravel Enhancement Projects

| Reservoir (Dam) | River | Year | Vol. Emplaced ($m^3$) | Cost | Agency | Remarks (Source) |
|---|---|---|---|---|---|---|
| Camanche | Mokelumne | 1990<br>1992 | 76<br>230 | $20,000<br>$6,300 | EBMUD | (Joe Miyamoto, EBMUD, pers. comm. 1991)<br>(Roger Hartwell, EBMUD, pers. comm. 1993) |
| Shasta[a] | Sacramento | 1979 | 6,648 | — | CDFG | 85% of emplaced gravel (D50=13.5, D84=24 mm) was removed by high flows in Jan. and Feb. 1980 (Parfitt & Buer 1980)[d] |
| Shasta[a] | Sacramento | 1988 | 76,410 | $250,000 | CDFG | Gravel placed at mouth of Salt Ck., 1 mi downstream of Keswick Dam, funded by USBR (Denton 1991) |
| Shasta[a] | Sacramento | 1989 | 687,690 | $200,000 | CDFG | Gravel placed at mouth of Salt Ck., 1 mi downstream of Keswick Dam, funded by USBR (Denton 1991) |
| Shasta[a] | Sacramento | 1990 | 12,226 | $2,200,000 | DWR, CDFG | Sacramento R. From Keswick Dam to Clear Ck. Funded by Delta Pumps Fish Protection Agreement 1986 (Denton 1991) |
| Shasta[a] | Sacramento | Planned 1991 - 2000 | 6,113 | $19,800,000 | DWR, CDFG | Sacramento R., Keswick Dam downstream. Cost based on $22/yd$^3$ (Denton 1991) |
| Los Padres | Carmel | 1990 | 31<br>612 | $580<br>$82,000 | MPWMD<br>CRSA | Gravel emplaced by CCC hand labor in potential spawning sites (cost does not include 1991 sup./planning cost or labor); redistributed by 1991 flood (RI~2yr)(D. Dettman, MPWMD, pers. comm. 1991) |
| Iron Gate | Klamath | 1985 | 1,666 | $136,000 | CDFG | Includes channel work costs, bed excavation of 9,800 yd$^3$ & boulder placement (R. Painter, CDFG, pers. comm. 1991) |
| Kent (Peter's) | Lagunitas Ck. | 1991 | 41 | $800 | MMWD | Cost does not include value of volunteer labor to emplace gravel, transport, etc. (Newspaper article in *Point Reyes Light*, Nov. 7, 1991) |
| Courtwright | Helms Ck. | 1985 | 5 | $12,000 | PG&E | Helicopter used to drop gravel in narrow gorge by hopper (T. Lambert, PG&E, pers. comm. 1992) |

TABLE C.1. (Continued)

| Reservoir (Dam) | River | Year | Vol. Emplaced (m³) | Cost | Agency | Remarks (Source) |
|---|---|---|---|---|---|---|
| Clair Engle (Trinity)[b] | Trinity | 1989 | 1,490 | $22,000 | USBR | Gravels emplaced at 5 sites (R. Smith, USBR, pers. comm. 1991) |
| Folsom[c] | American | 1991 | 764 | $30,000 | Sac. County | Gravels emplaced below Nimbus Dam as mitigation for disruption of spawning beds at Sunrise Ave. Bridge (F. Meyer, CDFG, and J. Purvis, Teichert Construction, pers. comm. 1991) |
| Unnamed | Lee Vining Ck. | 1991 | 229 | $4,500 | LADWP | Cost reflects delivered price of gravel (at $15/yd³ only, does not include planning, design, or placement costs (S. English, pers. comm. 1991) |
| Grant Lake | Rush Ck. | 1991 | 917 | $18,000 | LADWP | Cost reflects delivered price of gravel (at $15/yd³ only, does not include planning, design, or placement costs (S. English, pers. comm. 1991) |
| Oroville | Feather | 1982 | 2,292 | nya | CDFG | Gravel emplacement part of larger project involving maintenance of spawning channels DWR and gravel ripping (DWR 1983; F. Meyer, R. Painter, CDFG, pers. comm. 1991) |
| Oroville | Feather | 1987 | 1,559 | nya | CDFG | Gravel emplacement part of larger project involving maintenance of spawning channels DWR and gravel ripping (DWR 1983; F. Meyer, R. Painter, CDFG, pers. comm. 1991) |
| Pleasant Valley | Owens | 1962 | 634 | nya | LADWP | Gravel imported to artificial spawning channel (Hazel, et al. 1976) |

(a) Reregulated by Keswick Dam
(b) Reregulated by Lewiston Dam
(c) Reregulated by Nimbus Dam
(d) All references in this table can be found in Kondolf and Matthews (1993).

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